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DEALING WITH TECHNICAL PROBLEMS
RELATING TO THE PRODUCTS, PROCESSES AND INVESTIGATIONS OF
THE PHILIPS INDUSTRIES

SCIENCE AND INDUSTRY

by H. B. G. CASIMIR.

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During the Golden Anniversary of the State of Oklahoma, on June 17, 1957, an international symposium was organized at Oklahoma City under the general heading: science, industry and education. A number of the foremost leaders of research institutions from different countries were invited to give their views on problems related to this general theme. The following article is a slightly abridged version of the address delivered by Prof. H. B. G. Casimir, director of the Philips Laboratories and member of the board of directors of the Philips Industries.

The subject of the relations of science, industry and education is an extensive one about which a lot can be said and has been said, and it would be useless if I tried once more to survey the whole field. I shall therefore concentrate on three statements of which I trust that they are sufficiently controversial to form a contribution to discussions on this subject.

The first one relates to laboratory administration and runs as follows: in an industrial research laboratory it is impossible to relate research products budgetwise to industrial and commercial projects. Any attempt at operating a laboratory on a budget system will either be detrimental to research itself or it will lead to a mild form of cheating which makes the whole system illusory.

My second statement is that although industry is for its future dependent on fundamental research, very few fundamental results have come, will come or should come out of an industrial research laboratory.

My third statement: it is wrong to regard education and research as two distinct and separate tasks of a University.

Before proceeding any further I should make it clear what I understand by the words fundamental research, research, development and so on.

I shall describe what one might call the spectrum of research. At one end of the spectrum there is Fundamental Research with very heavy capital F and capital R. I should like to define this as research dealing with entirely new phenomena connected with basically and philosophically new principles in the description of nature. It is easy to give examples: the work of Faraday and Maxwell on the electromagnetic field, the work of Boltzmann and Gibbs on the kinetic explanation of thermodynamic phenomena, Einstein's theory of relativity, Bohr's quantum theory of the atom and the new quantum mechanics of Heisenberg, Schrödinger and Dirac belong clearly to this category. Next comes fundamental research with a more modest f and r. The aim is still the understanding of nature, but it is dealing with fields in which the basic principles are well understood. Work on molecular spectra, solid-state physics, electromagnetic diffraction, hydrodynamics would come in this group.

My next category is target-research. The method of working, the scientific approach is still the same, but now one has a definite technical target in mind: one is for instance no longer working on fluorescence in general, but is trying to find a substance which under electron bombardment gives a good output of red light with a more or less specified delay-time. In the engineering field a similar type of work is what I like to call project-research, but what is also frequently covered by the words advanced development. By this I understand work aimed at realizing a concrete technical object but with the qualification that it is still uncertain to what extent the thing we have in mind is possible. The first people who started to build electron microscopes knew almost nothing about the potential possibilities of this instrument; for those who came later in the field it was evident that an electron microscope could be built, but it was impossible to tell beforehand what resolving power would be obtained with a reasonable amount of work. At present, unless we go to the very furthest limits of resolving power, it is almost possible to lay down specifications beforehand and to make a reasonable estimate of the cost of this development in time, manpower and facilities. This I consider characteristic of development, the possibility to estimate more or less accurately what is required to make a prototype of more or less specified characteristics. I have twice inserted more or less; this is not very elegant phrasing, but anyone who has had to do with the administration of research and development will agree that it is a necessary precaution.

Next in my list appear factory-engineering and trouble-shooting, activities that are related to development, but that often also give rise to problems of target-research. In our own organization the end of the spectrum is application-research, the work on specific applications of our own products. This would comprise such things as illumination-engineering, the art of adapting public address systems to existing buildings or the adaptation of a high-frequency furnace to a special industrial process. As I said before, this application-research has in our firm a somewhat separate position because of the nature of its relations with industrial and commercial activities, but from a more scientific and technical point of view it is a combination of the former types.

Perhaps the word spectrum is not too badly chosen for there is in reality a continuous transition and just as it is difficult in the solar spectrum to tell whether a certain colour is a bluish green or a greenish blue, one may differ in opinion about whether a certain type of work is target-research or development, and so on.

In our organization each industrial division is responsible for its own development, factory engineering and application work, whereas fundamental research, target-research and project-research or advanced development are carried out in our central research laboratory. I believe that this division has been found useful by all organizations that are dealing with a wide and diversified range of products. The basic principles underlying a simple radio receiver and a modern radar installation are not too different, but there is such a tremendous difference in style of technical realization that it is hard to imagine a central research and development organization able to cope competently with the development work for both the one and the other.

If you remember my definitions, you will notice that the work of our factory laboratories begins where results are reasonably certain and where costs can be predicted. The work in the research laboratories may be equally practical or applied in character, but there is always this distinction that there is a much higher degree of uncertainty and this leads directly to my first statement. In the case of factory development it is reasonable to ask whether the cost of developing a product can be earned back by sales of that product. Development costs of a specified product are part of the cost price of that product. It is impossible to make a similar breakdown of the expenses of a research laboratory: some of the work may not lead anywhere — much of it will later turn out to be useful in fields vastly different from those envisaged when the work was started. We originally studied ferromagnetic ferrites for a special application in carrier telephony: many years later we found that the bulk of our production goes into television receivers. From a long-range point of view our work on ferromagnetism has been succesful and profitable but if our nascent carrier telephony department had had to bear the initial expenses it would have been killed right at the start.

But, you will ask, why should the cheating come in? The reason is that the total budget of a research laboratory is determined fairly accurately by the number of scientific workers: if in a given field of research and a given country you want to have a laboratory where a number of research workers can work efficiently and are adequately provided with technical assistance, workshops and so on, then the cost per research worker will always come out the same. Further, a research institution should aim at continuity of staff, for it is an exception that a man, however competent he may be, does valuable work during his first half year or so in new surroundings, and some of the best research workers become productive only after several years. A slow and continuous flow of people is all right, but one should try to avoid discontinuous expansions or reductions.

The art of running a laboratory on a budget system consists therefore in splitting a sum total that is known beforehand into a number of separate items in such a way that those in charge of appropriations will fall for it. If I had to do this in my own institution I would start arguing in the following way: we have a fairly large group working on fluorescence. It is useful to both our lampworks and our cathode-ray tube factory. On the other hand some fairly abstract mathematical work on electron optics is being done, for which it is hard to find a suitable place on the budget.

Should the latter fact induce us to discontinue this work, which we think in the long run may prove quite useful? Better place it under the general heading of cathode-ray tubes, which sounds reasonable, and in order not too overload the budget for this division, put the whole fluorescence research on the budget for the lighting division, which is less crammed. And so on. It is this kind of artificial splitting and combining which I had in mind when I spoke of a mild form of cheating. Fortunately in our company we have done away with this system altogether. The research laboratories as a whole are each year allotted a lump sum calculated in such a way that it provides reasonable working conditions for the number of people employed and leaves room for slow expansion. Only in the case of large capital investments, new buildings, etc., do we apply for an additional budget. Of course we have to keep an eye on expenses, but no reference is ever made to a budget for a specific project. The notion of such a budget simply does not exist.

In my dictionary of English slang I find "Dutch reckoning" defined as a lump account without particulars. I am proud of being a Dutchman, so you can hardly be surprised that I consider this type of reckoning ideally suited to the needs of a research laboratory. So much about my first statement.

My second statement was that industry depends on the results of fundamental research — and here I mean to say Fundamental Research with capitals — but that such results do not come out of industrial laboratories. History gives ample evidence for this. Electrical engineering could not even be imagined without the pioneering work of Faraday and of Maxwell whose work in those days was entirely outside the scope of existing industries. There would be no radio without the work of Maxwell and Hertz, but it did not occur to the electrical industries of those days to do the work by which Hertz justly became famous. Speaking and working about electrons was almost anathema to the electrical engineer at the turn of the century, but today an evergrowing industry is based on the very notion of electrons. No company interested in power plants could dream that the work of the Curies, Rutherford and others would eventually lead to a new source of power. An industry may take a long range point of view, it may encourage fundamental research, it may not require results of immediate practical value, but it cannot be expected to work on basic principles and phenomena for which even our most vivid imagination cannot foresee whether, or in what field, they will find applications. Today at the very front of science, physicists are working on elementary particles, on concepts like parity, on the relations between mesons and nuclear forces. No one can foresee to what this will lead. No industry laboratory could be expected to do cosmic-ray work on a large scale or to be the first to build at its own cost a cosmotron, and yet if we deny the possibility of future applications we are probably just as shortsighted as the power engineer early in the century who derided electrons. The places for Fundamental Research are the University laboratories.

Here someone might interrupt me and object: What about the transistor? Now first of all let me say that the transistor is not only an extremely important and useful device that will have a far reaching influence on the whole field of electronics, but that the research that led to the transistor is a very beautiful piece of work indeed, combining well planned and yet imaginative experiments with a penetrating and elegant theoretical analysis. So it is not a question of grapes being sour: on the contrary they are very sweet; and though they may have been a little bit too high for us to pick, all the electronic industries got a generous helping after the picking. And yet I think the transistor is a good example for my thesis. So allow me to go into technical details for a moment and let me review the basic thoughts that play a role in the transistor.

First of all the idea of electrons, a notion connected especially with the theoretical work of my countryman Lorentz and the experiments of J. J. Thomson. Next the statistical theory of matter and its relation to thermodynamics (Maxwell, Boltzmann, Gibbs). The application of such methods to the motion of electrons led, in the hands of Lorentz and of Niels Bohr in his little known thesis, to important results. But there remained a number of very puzzling questions: How it is possible that the conduction electrons do not contribute appreciably to the specific heat; how can we imagine that an electron can move freely through a metal; and how is it possible that the sign of the so-called Hall effect is sometimes as if the current through a metal were carried by positive carriers, although we know that electrons are negatively charged? The solution of these riddles required entirely new notions.

The first was solved by the Fermi-Dirac statistics, a modification of classical statistical theory, brought about firstly by a recognition of the existence of quantum states and secondly by the Pauli exclusion principle. The application of Fermi-Dirac statistics to the motion of the electrons in a metal was worked out by Sommerfeld and turned out to be a great improvement. The solution of the second problem is due to Bloch and Peierls after some preliminary and more qualitative work of Houston. It is based on new quantum mechanics where electrons are described by waves, a theory connected with the names of de Broglie and Schrödinger. It is found that these electron waves are free to move in a perfectly periodic field of force and the analysis of such waves by Brillouin and others led to the notion of electron bands. The third riddle was solved by Peierls; he was the first to introduce the notion of a hole in a filled electron band and to show that it behaves as it it were a positive electron. From then on the problems became less fundamental, but the essential ideas about semiconductors were still mainly the result of University work. Now the one new principle that was added by the Bell people to existing notions was the idea that electrons can persist for some time in p-type germanium, that is, germanium containing such impurities that the conduction is due to the motion of holes; similarly injected holes can persist for some time in n-type germanium. This is both an important experimental fact and an interesting theoretical idea, but from a philosophical point of view it is certainly not on a par with the great new ideas of quantum mechanics. The work on transistors is essentially a brilliant and novel application of known principles, that would be a beautiful piece of physical research anyway, but happens to be of great technical consequence too.

Once more, the fundamental notions that are required by industry are coming from the universities.

I would add the following. The rise of an industry depends on leadership that recognizes among other things the necessity of research. But when it comes to fundamental research we are again faced with the same situation on a different level. For the future of a single industry it is essential that it be broadminded with respect to its own research; for the community as a whole and for the future of all its industries, it is essential to support also the most abstract type of fundamental work. Industrial laboratories are part of a far-seeing policy of industrialists. Wise statesmanship of the leaders of a nation will result in sponsorship of academic research.

Why then my third statement? Why is it wrong to say that Universities have not only an educational task but should *also* carry out research? Because this way of looking at things shows a basic misunderstanding of the nature of a University. It is the task of a University to live a scientific life and to initiate a younger generation in this way of thinking. This initiation requires instruction in certain techniques, but these are only means to a goal. There is only one form of real higher education and that does not consist in listening to lectures, in performing classroom experiments or in solving textbook problems: it consists in struggling on the borderline of knowledge, with the unknown and the unexpected, under the guidance of an inspired and inspiring teacher.

I have discussed, in the foregoing, one or two aspects of the relations between science and industry. I have emphasized the importance of industrial research for industry and of academic research for industrial research. But that is not the whole story. Although our technical civilization is the result of a joining of forces of philosophical inquisitiveness and industrial zeal, our desire to understand nature is not only justified by its practical importance. It corresponds to a noble urge of the human race that is also an aim in itself. Even the most die-hard materialist feels dimly that the mathematician dealing with an impressive edifice of abstractions and the astronomer probing the structure of the universe are doing valuable things and are in some way contributing to the richness of human experience.

There enters some of this even in a simple piece of applied research. To feel that one's work is not only of practical use but has also inherent value and beauty, is one of the things that make life worth living. We research people should count ourselves fortunate beings.

AN EXPERIMENTAL PYROMETER USING A PHOTOTRANSISTOR AND DESIGNED FOR RADIO-TUBE INSPECTION

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In radio-tube manufacture it is important to be able to measure the temperature of various parts of finished tubes while they are in operation. Sometimes it is desired to perform a large number of such measurements in a short time.

Often it is clearly out of the question to use an instrument that has to be placed in contact with the object (such as a thermometer or thermocouple); recourse must therefore be had to one that works at a distance, i.e. that responds to the radiation from the object whose temperature is to be measured.

The optical pyrometer is the instrument most commonly used for this purpose. In this, an image of the surface being investigated is formed in the plane of the filament of a small incandescent lamp. The lamp current is adjusted to a value such that the eye is no longer able to distinguish the incandescent filament from its background. The temperature of the object can be derived from the value of the lamp current.

The method can of course be employed only where the object radiates light. The lowest temperature that can be measured thus lies round about 630 °C [1]). The temperature of the cathode of a vacuum tube ($\sim$700 °C) [1]) can thus be determined by this method. For accuracy in the measurement of such low temperatures, however, it is necessary to work in a dark room. Also the work is tiring to the eyes. It is only possible to carry out a large number of measurements in a short time if experienced observers are available who are accustomed to the work [2]). It is quite impossible, with the optical pyrometer, to investigate those parts of a radio tube whose normal working temperatures are lower than that of the cathode.

This state of affairs has prompted the search for a method in which an objective radiation detector would take the place of the human eye, the need for experienced observers thus being done away with, and which would moreover allow the range of measurement to be extended to lower temperatures.

It has been found that these requirements can be satisfied by making use of a transistor that is sensitive to radiant energy (Philips type OCP 71 germanium phototransistor). A diagram of a pyrometer equipped with one of these transistors is shown in *fig. 1*. (This pyrometer was built for experimental purposes only; it is not marketed.) The optical system is constructed largely from a single-lens miniature reflex camera: the lens [3]) of the camera (L) throws a full-sized image of the object under investigation (O) on to a diaphragm (D). The light-sensitive region of the transistor is located immediately behind the opening in the diaphragm. This opening has a diameter of only 0.6 mm. Since the image is of the same size as the object, the transistor "sees" a circular patch of the latter that is likewise only 0.6 mm across; consequently this pyrometer can be used to make spot measurements of temperature over quite small objects, such as the electrodes of radio tubes [4]). The location of the spot under measurement is found by turning mirror AM into position AM'. The object — illuminated by the normal ambient light in the room — then appears on the ground-glass screen G. D', a mark on the screen, indicates the spot that is being "seen" by the transistor [5]).

The beam from the object is chopped at a frequency of 175 c/s by a rotating perforated disc (C). Consequently the current through the transistor exhibits an A.C. component of 175 c/s whose amplitude is a measure of the incident radiation density. The ripple signal is fed into a narrow-bandwidth amplifier selective to frequencies in the vicinity of 175 c/s. The amplifier output is indicated on a meter. By chopping the beam and using a selective amplifier, the meter-reading is determined almost solely by the incident radiation and is independent, or practically so, of random fluctuations in the transis-

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[1]) These values are *apparent temperatures* determined with an optical pyrometer calibrated with a black body, usually called the "brightness temperatures", see below, small print.

[2]) Results obtained by inexperienced observers exhibit a standard deviation that is generally greater than 5 °C; with experienced observers the standard deviation is 1 °C.

[3]) Relative aperture 1 : 2.9; $f = 50$ mm.

[4]) Lead-sulphide photo-cells and certain other photoconductors are also very sensitive in the infra-red and are often used as the detector element in radiation pyrometers. PbS cells are, however, unsuitable for our purpose for the following reasons: *a*) Their high sensitivity is obtained only for radiation of a considerable range of wavelengths, extending far into the infra-red; measurements of temperatures through glass (e.g. through the envelope of a radio valve) would therefore involve working with far less than the optimum sensitivity. Also the imaging of the object by means of lenses would give rise to complications. *b*) The sensitivity per unit area of the PbS cell is much less than that of the phototransistor.

[5]) During assembly of the pyrometer, account must be taken of the chromatic aberration of the optical system: the infra-red radiation, where the transistor is at its most sensitive, is brought to focus somewhat further from the lens than visible light.

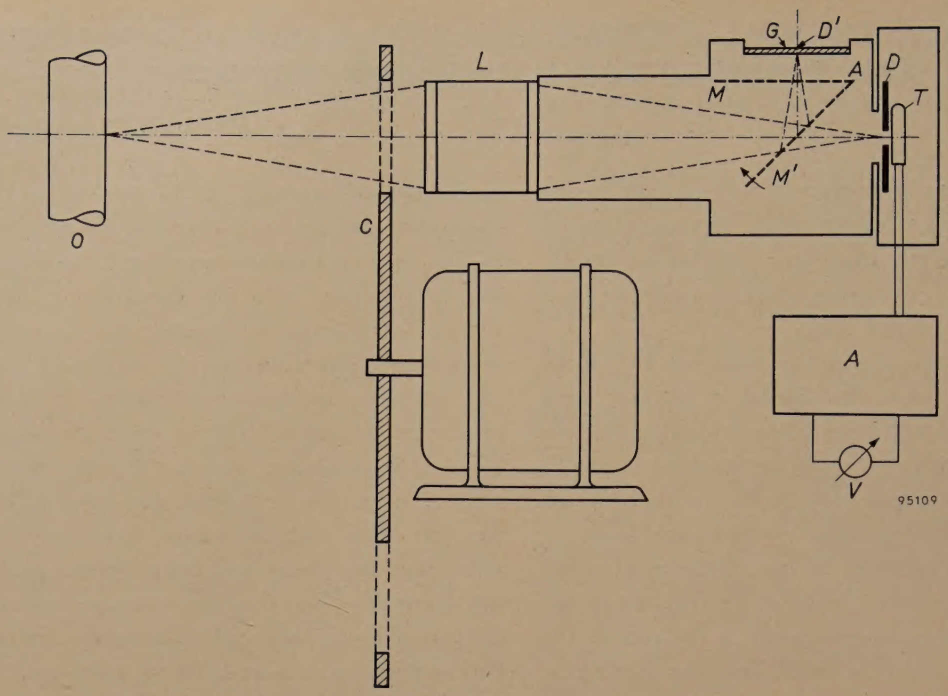

Fig. 1. Schematic diagram of radiation pyrometer based on phototransistor. A full-sized image of the object *O* (the anode of a radio tube, for example) is projected by the lens system *L* on to diaphragm *D*, behind which is the phototransistor *T*. The perforated disc *C*, mounted on the spindle of a synchronous motor, chops the beam at a rate of 175 times per second. With the mirror *AM* placed in position *AM'*, the instrument can be aligned so that the point whose temperature it is desired to measure forms an image coinciding with mark *D'* on ground-glass screen *G*. Variations in the transistor current are converted into voltage variations: components with a frequency of 175 c/s pass through the selective linear amplifier *A*. The output voltage, after being rectified, is measured by means of meter *V*.

tor current ⁶). Also, the amplifier design is such that fluctuations in its supply voltage have little effect. The selective amplifier is also responsible for a considerable improvement in the signal-to-noise ratio; noise frequencies lying outside the pass-band are eliminated. Amongst other things, this has an important bearing on the question of extending the range of measurable temperatures, for the signal-to-noise ratio sets a lower limit to this range. For the present apparatus the lower limit is at an *apparent temperature* of about 200 °C (see below, small print). A high signal-to-noise ratio is obtained not only by reducing noise but also by having the strongest possible signal; this means that the relative aperture of the optical system should be large. The uncertainty (standard deviation) in the measurement of temperature with this apparatus is approximately 1 °C, and is thus about the same as that involved in measurements with the optical pyrometer by experienced observers.

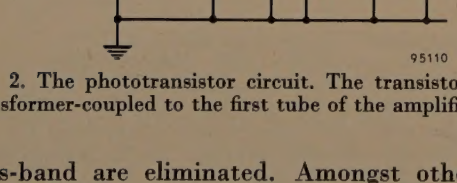

Fig. 2. The phototransistor circuit. The transistor output is transformer-coupled to the first tube of the amplifier.

Fig. 2 shows the transistor circuit and the manner in which variations in the current through the transistor are converted into variations in the grid voltage of the first tube of the amplifier just referred to. The variations in grid voltage are proportional to those in the transistor current, the factor of proportionality being equal to the product of the input impedance of the transformer at a frequency of 175 c/s (700 kΩ) and the transformation ratio. Transformer coupling is favourable from the standpoint of signal-to-noise ratio, the mean noise voltage across an impedance (within a given frequency interval) being proportional to its D.C. resistance (which is only 20 kΩ for both windings of the transformer). The second and third stages of the amplifier are selective (their resonance frequencies being 169

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⁶) Fluctuations in the transistor current may be due to stray light falling on to the transistor and, in particular, to changes in its temperature. It is possible, in principle, to reduce such effects by using a bridge circuit comprising two selected transistors with matched properties.

and 181 c/s respectively; both have a quality factor Q of 17). In this way a frequency-response curve is obtained that is almost horizontal between 170 and 180 c/s and drops steeply outside these two frequencies (*fig. 3*). The output stage (which is not selective) is connected to a precision milliammeter (with an accuracy of 0.5%) via a transformer and a full-wave rectifier consisting of four germanium diodes. The reading given by the meter is proportional to the amplitude of the variations in the transistor current. An attenuator inserted between the first and second stages of the amplifier allows the amplification to be attenuated in six steps down to a factor of 1000. Under conditions of maximum amplification, full-scale deflection of the meter needle corresponds to a 3 μV variation in the grid voltage of the first tube. The linearity of the amplifier is excellent. The amplification factor varies by less than 1% for different signal strengths. The mean noise (and interference) voltage on the grid of the first tube is approximately 0.2 μV.

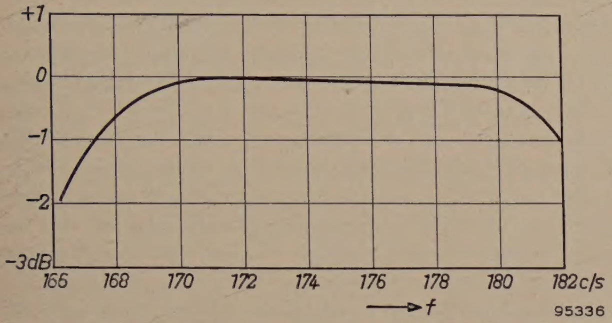

Fig. 3. The frequency response curve of the amplifier. Between 170 and 180 c/s the amplification varies by less than 0.3 dB; beyond 165 c/s and 183 c/s, amplification falls off by more than 3 dB.

Since the current through a transistor depends on its temperature, the phototransistor used in this apparatus is mounted in an aluminium block through which water from the mains supply is circulated. In this way the temperature of the transistor is reduced and stabilized at approx. 16 °C. Lowering the temperature has a favourable effect on the signal-to-noise ratio.

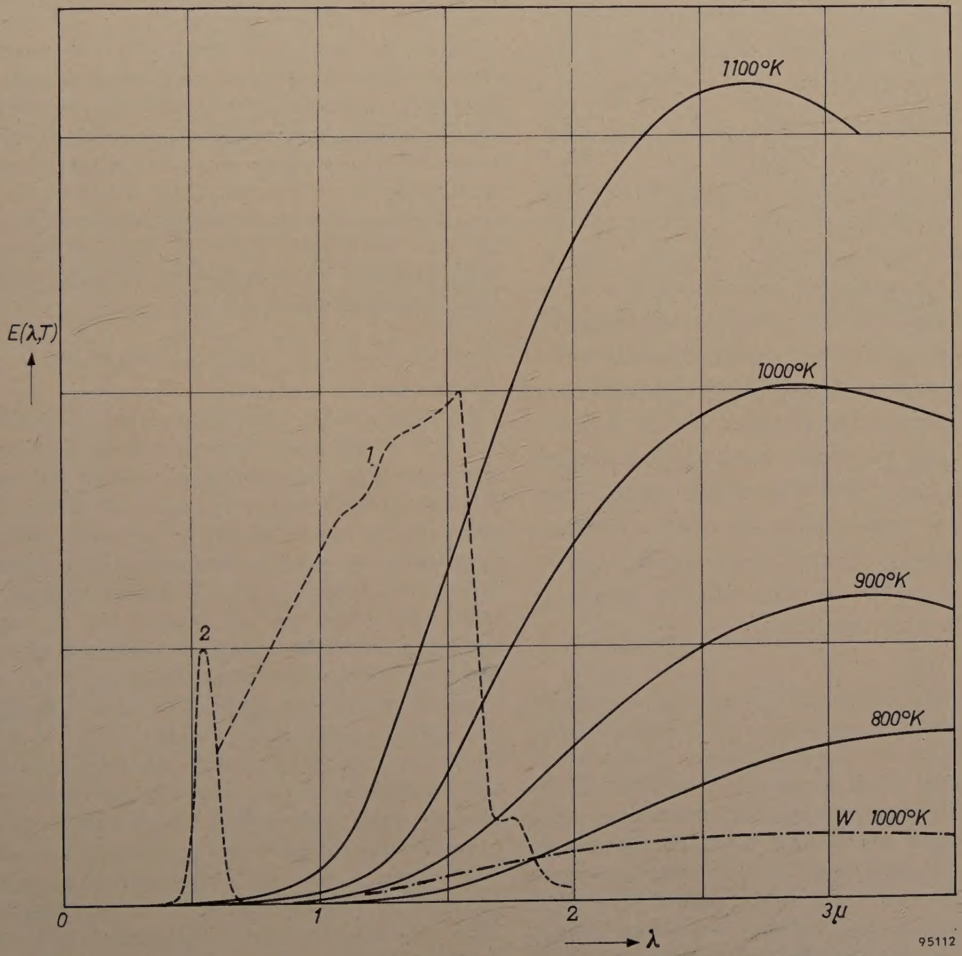

Fig. 4. Spectral energy distribution of the radiation from a black body at 800, 900, 1000 and 1100 °K (fully-drawn curves). The $E(\lambda,T)$ curve for a tungsten source at 1000 °K (chain-dotted line) is shown for the purpose of comparison. Dotted line *1* represents the spectral sensitivity of the OCP 71 transistor in arbitrary units; dotted line *2* is the sensitivity curve of the human eye, also in arbitrary units.

To reduce the risk of electrical leakage from the transistor, it is coated with a thin skin of a water-repellent resin prior to mounting, by treatment with dimethyldichlorosilane, $(CH_3)_2Cl_2Si$.

The conditions under which the new pyrometer is used may be illustrated with the help of *fig. 4*. The fully-drawn curves in this figure are those of the spectral energy distribution $E(\lambda,T)$ of radiation from a black body at various temperatures T between 800 °K and 1100 °K. Dotted line *1* indicates the spectral sensitivity of the transistor on an arbitrary scale; the peak of the curve occurs at 1.55 μ. Dotted line *2* is the sensitivity curve of the human eye, which of course governs measurements made with the optical pyrometer. The figure shows that the new pyrometer is sensitive to a wider band than the optical instrument, being able to detect wavelengths as long as 2 μ. Thus its sensitive range is not limited, as that of the optical pyrometer is, to the extreme tail of the energy spectrum from bodies at about 1000 °K; the new instrument is sensitive to wavelengths at which the radiation density is considerably higher.

In accordance with the usual practice, the pyrometer is calibrated with the aid of a black body, each meter-reading being correlated with a certain temperature. A source of radiation other than a black body that gives rise to the same meter-reading as a black body at a temperature Z may be said to have an apparent temperature of Z; its true temperature T is higher. If, with this instrument, it is to be possible to determine the true temperature from the apparent temperature, further calibration has to be undertaken; this involves measuring the temperature of the object in some other manner, with a thermocouple, for example. For some materials it is almost impossible to measure the true temperature, and in such cases one must make do with measurement of the apparent temperature; knowledge of this does in fact suffice for the solution of many problems in radio-tube manufacture.

In principle, the familiar formulae of radiation pyrometry might be employed for deriving the true temperature T from the apparent temperature Z. The relationship between T and Z becomes comparatively simple if the pyrometer satisfies two conditions: *a*) that it is sensitive only to radiation falling within so narrow a wavelength interval that it can be regarded as monochromatic, and *b*) that this wavelength is short compared with the wavelength of the peak of the radiated spectrum.

The energy distribution of the radiation emitted by a black body is given by Planck's formula. However, for $\lambda T \ll C_2$ (where $C_2 = hc/k = 1.438 \times 10^{-2}$ m.°K, the second constant in Planck's formula), i.e. for the shorter wavelengths of the emitted spectrum (condition *b* above), Planck's formula may be replaced by the simpler formula of Wien:

$$E(\lambda,T) = 2\,C_1\lambda^{-5}\,e^{-C_2/\lambda T}. \quad \dots\dots \quad (1)$$

The transistor is, in fact, not sensitive to wavelengths longer than 2 μ, which is a short wavelength in comparison with $\lambda = C_2/T$ for bodies at the temperatures that interest us, viz. 1000 °K ($C_2/1000 \approx 14\ \mu$). Under these circumstances, Wien's formula deviates, in fact, less than 0.1% from Planck's formula.

The requirement of monochromatic radiation (condition *a* above) arises from the fact that the bodies whose temperatures are to be measured are, in general, selective emitters, i.e. non-black bodies whose emissivity varies with the wavelength. If we consider only the radiation within a given small wavelength interval $d\lambda$, a non-black body emitting the same energy as a black body (at another temperature) may be said to have an apparent temperature Z numerically equal to the true temperature of the black body; the true temperature T of the non-black body is of course higher. This may be expressed by equating the energies emitted:

$$E(\lambda, Z)d\lambda = e(\lambda, T)d\lambda\,, \quad \dots\dots\dots \quad (2)$$

where e represents the energy distribution function for the non-black body.

From the definition of the emissivity $\varepsilon(\lambda,T) = e(\lambda,T)/E(\lambda,T)$, we re-write (3) as:

$$E(\lambda,Z) = E(\lambda,T)\,.\,\varepsilon(\lambda,T)\,. \quad \dots\dots \quad (3)$$

If, then, our pyrometer responds only to monochromatic radiation, within a specified interval $d\lambda$, at which the emissivity ε is known, the true temperature T of a body can be calculated from the apparent temperature Z which is measured on the black-body calibrated pyrometer. If ε does not vary too rapidly with wavelength, the true temperature could be calculated with reasonable accuracy even when the pyrometer responds to a small range of wavelengths. (This is indeed the case in the optical pyrometer.) The relationship between T and Z is now given by substituting (1) in (3). The fact that we may use Wien's formula (1) in the present circumstances makes this relation very simple:

$$\frac{1}{Z} = \frac{1}{T} - \frac{\lambda}{C_2}\log\varepsilon(\lambda,T)\,. \quad \dots\dots \quad (4)$$

Experiments show that for temperatures between 500 °K and 1000 °K the new pyrometer behaves as if it were indeed responsive only to radiation of a single wavelength. *Fig. 5* shows the response of the pyrometer to radiation from a black body, plotted logarithmically in arbitrary units against the reciprocal of the absolute temperature. The values fall almost exactly on a straight line: this implies response to a single wavelength (take logs of equation (1); the equation then represents a straight line if λ is constant). The slope of the line in fig. 5 corresponds to a wavelength of 1.51 μ.

Having shown that conditions *a*) and *b*) are both satisfied, we might now expect that we could apply (4) to obtain the true temperatures of bodies from the measured apparent temperatures. Unfortunately, however, (4) can rarely be applied in practice owing to the lack of reliable data on the emissivities of many of the materials used in electron-tube manufacture.

Of course, if the true temperature of an object has been measured by some other method, it is quite possible to proceed in the reverse direction and to determine ε from the pyrometer response. This is, of course, the usual procedure. The response curve appropriate to nickel appears in fig. 5 as a dotted line. This curve likewise proves to be straight and, moreover, to be parallel to that for the black body. From the vertical distance between these straight lines the value of ε can be calculated (see definition of ε, above). Its value, which is independent of temperature (the lines being parallel), is found to be 0.22.

The disparity between the true and the apparent temperatures is a good deal greater with the transistor pyrometer than it is with the optical instrument [7]). For nickel at a temperature of 797 °C, the disparities are 139 °C and 45 °C respectively.

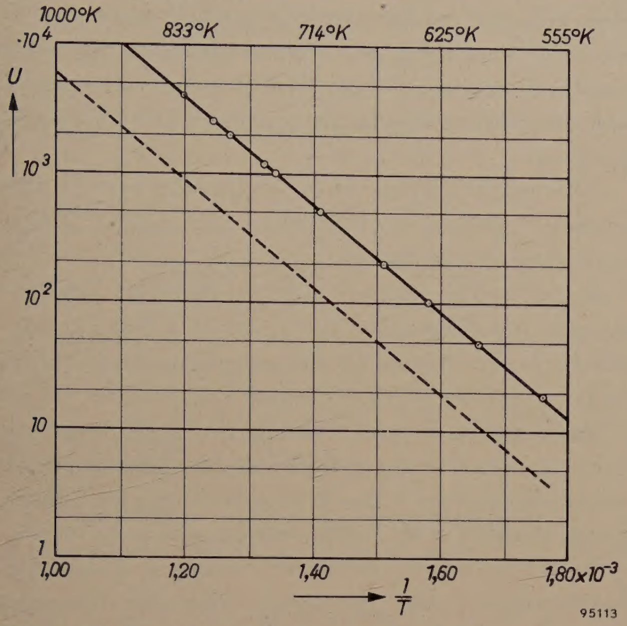

Fig. 5. The logarithm of U, the response of the pyrometer (in arbitrary units), as a function of the reciprocal of the absolute temperature. The fully-drawn curve refers to a black body, the dotted one to a nickel source. Both curves are straight; moreover, they are parallel.

It is particularly convenient, from the practical standpoint, that the transistor is insensitive to radiation of wavelengths longer than about 2 μ. It is possible, in consequence, to measure the temperatures of electrodes of finished radio tubes without corrections having to be made on account of radiation absorbed by the glass envelope; the amount of absorption in glass of this thickness only becomes significant for wavelengths longer than 2 μ. On the other hand, of course, the instrument cannot be used for measuring the temperature of the envelope itself. Reflection from the surface of the glass does, however, have to be taken into account. The simplest way of doing so is to carry out the calibration procedures referred to above with reference objects that are likewise behind glass.

As already stated, the lowest measurable temperature is determined by the signal-to-noise ratio. In an instrument now being constructed, in which the system of lenses is replaced by a mirror with a very large aperture, the signal-to-noise ratio will be considerably higher and the range of measurement will consequently extend to even lower temperatures. In addition, the rotating disc in this instrument will be inserted between the optical system and the transistor, close to the diaphragm. This will allow the size of the disc and the mechanical power unit to be considerably reduced, so that it will be possible to combine them with the camera in one assembly. By virtue of this the new instrument will be a portable one.

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[7]) From (4) it can be shown that, for any given temperature, this disparity is approximately proportional to λ. In the measurement of temperature of metals, the effect is generally reinforced by a fall-off in the spectral emissivity of the metal at the longer wavelengths.

ENCLOSED WELDING OF RAIL SECTIONS

621.791.75:625.143

One very well-known practical consequence of thermal expansion is that enough space has to be left between the rails of the permanent way to allow them to expand to the anticipated maximum without any danger of buckling. Now the railway authorities would be glad enough to do away with these gaps between rails, for their elimination would result in an immense saving in maintenance on the track and rolling stock. It has been estimated that no less than 80% of maintenance costs are attributable to jolts set up as trains pass over the gaps. The reduction of jolting and noise would also mean more comfort for the passenger. However, the danger of buckling has always made the gaps a necessary evil.

In recent years there has been a change for the better in this respect, thanks to improvements that have been made in most countries in the manner of laying the rails. Rails are now fixed more firmly to the sleepers, the distance between sleepers has been reduced, and the gravel metalling has been improved. These improvements have reduced the risk of buckling to such an extent that it has become unnecessary to leave gaps between sections of rail.

For fullest advantage to be taken of this fact, the ends of the sections should be welded together. Until a few years ago, however, no satisfactory method existed that could be employed for doing so *in situ*. Non-electric methods, such as thermite welding, do not in general give very good results. In arc-welding, one comes up against the difficulty that the greater part of the weld has to be made between vertical faces, namely the cross-sections of the web and head of the rail. This means that only a moderate welding current can be used, otherwise the filler metal will run away before it has time to solidify. Making the weld is therefore a slow job. Worse still, on account of the low current value too little heat is communicated to the parent steel on either side of the weld, which therefore cools quickly, becoming very hard and brittle in places owing to its high carbon content. The only electrical method of satisfactorily welding rails was resistance welding. That method cannot of course be employed on the track. It is in fact employed sometimes in railway workshops, but the overall length of the welded sections is restricted by the need to transport them on a string of flats wagons. A total length of 60 yards — 200 yards in exceptional cases — is not usually exceeded; and the problem of joining the welded sections together still has to be solved.

It became clear that the whole question was of more than local interest when, in quick succession, inquiries reached Philips Welding Department from four railway companies in different countries. We believe we have found the answer to their problem in the shape of an arc-welding method that was in process of development when the inquiries were made. For reasons that will become clear in a moment, we refer to the method as "enclosed" welding.

The investigations that eventually led to the enclosed welding method were undertaken in the following circumstances.

Metallurgical research had established that hydrogen was frequently the cause of unsatisfactory results in arc-welding by the normal method. Fairly large quantities of that element are present in the deposits from normal welding electrodes, such as mineral-coated and rutile electrodes. *Basic* types of electrode coatings ("low-hydrogen electrodes") have brought about a big improvement in this respect [1].

A characteristic difference between basic (or low-hydrogen) and non-basic electrodes becomes apparent when molten steel and liquid slag are present in equilibrium. Where non-basic electrodes have been used, the steel may contain slag inclusions and the slag itself may be free from metal (*fig. 1a*); when basic electrodes are employed, however, the weld steel is *slag-free*, although drops of metal may be present in the slag (fig. 1*b*). (It may be observed that the question as to which of the two states will result is not merely a matter of specific gravities.) It was clear that this particular property of basic

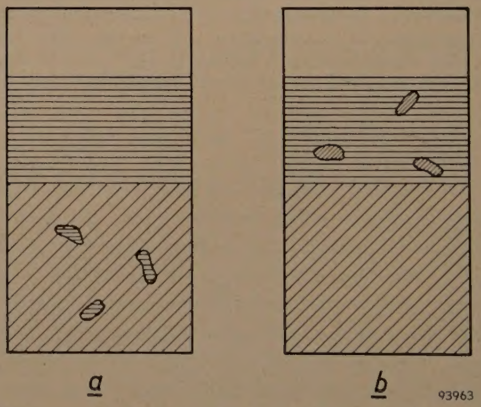

Fig. 1. Diagrams to show equilibrium states of molten steel and liquid slag when (*a*) non-basic electrodes have been used, (*b*) when basic electrodes have been used. In case (*a*) it is possible for slag to be present in the steel, but not for steel to be present in the slag; precisely the opposite applies in case (*b*).

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[1] J. D. Fast, Philips tech. Rev. 14, 96, 1952/53.

electrodes, which plays no part in ordinary welding, might assume a practical importance: even when working with a large weld-pool, it would be possible to obtain a deposit essentially free from the macroscopic slag inclusions that do a great deal to weaken a weld.

Our investigations, referred to above, were directed toward finding a practical way of exploiting this fact. After a series of tests, we arrived at the arrangement shown in *fig. 2* for making a *vertical* butt weld.

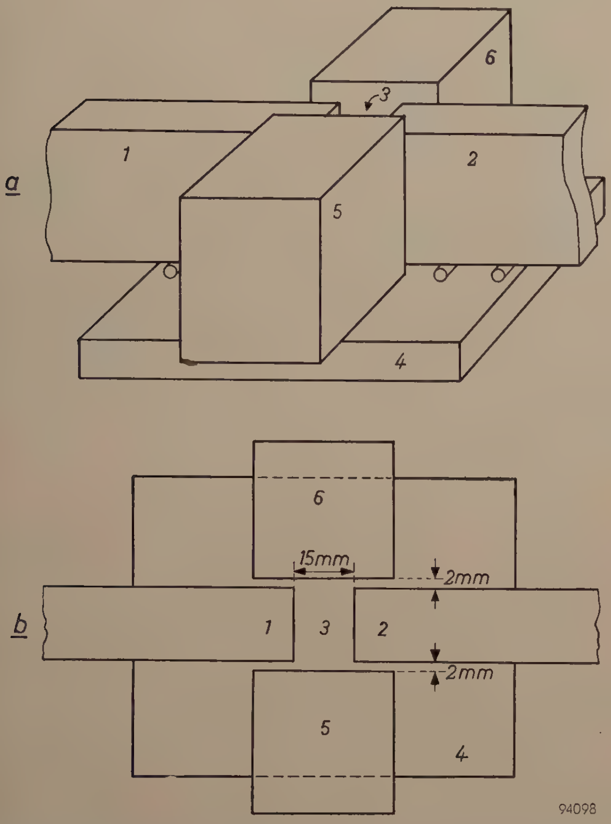

Fig. 2. Arrangement for enclosed welding of two steel bars *1* and *2*. The enclosure consists of a base-plate *4* and blocks *5* and *6*, all of copper. Welding is carried out inside the compartment *3*. The clearances through which the slag runs out are visible in the plan view.

Two steel bars *1* and *2* to be welded together, are arranged vertically with a gap *3* of about 15 mm between their edges. The bottom of the gap is closed by a copper base-plate *4*, and its sides are blocked by copper blocks *5* and *6*. A basic welding electrode is introduced into the compartment *3* thus formed, and the arc is struck against the lower part of one of the bar ends. A thick electrode (5 to 8 mm) and a correspondingly heavy welding current (250 A to 450 A alternating current) is preferably employed. A large pool of molten steel, with liquid slag on top of it, is now formed in the compartment. Since narrow clearances (2 mm) have been left between the workpieces and the copper blocks and base-plate — see view from above in fig. 2 — the thin liquid slag runs out through these openings, but the steel remains. The function of base-plate *4* and blocks *5* and *6* is rather similar to that of the moulds ("shuttering") used for concrete structures — they form a temporary enclosure for the concrete while it is setting.

These tests confirmed that, when basic electrodes are used, the deposited steel will be free of macroscopic inclusions if only it has remained molten for a long enough time. That condition appears to be satisfied by the arrangement shown in fig. 2, providing halts for electrode changing are of very short duration (when large cross-sections are being welded, dozens of electrodes are necessary for the one job). There is a big difference between enclosed welding and normal welding in layers: in the former the whole weld actually constitutes a single layer; in the latter case, thin layers up to the required number are deposited one on top of the other. As a result of this, and as a consequence, too, of the heavier welding current, the amount of heat applied per unit length of an enclosure-welded joint is about seven times as much as that applied per unit length and per layer in normal welding. In enclosed welding the parent steel facing the weld cools so slowly that no appreciable hardening takes place in the transition (heat-affected) zone. A second consequence of the rapid heating rate is that the work proceeds quickly. The components of the enclosure can be used over and over again, for hundreds of jobs. All that is necessary is now and again to regrind those faces that have roughened with use.

Although the process looked promising, it was found that even low-hydrogen electrodes still contained too much hydrogen for enclosed welding. The difficulty is that the high column of molten steel prevents the escape of the hydrogen [2]) which must be removed as the temperature drops. The enclosed welding of vertical and almost vertical joints only became a complete success once a special ("extra low-hydrogen") electrode had been developed. To prevent these new electrodes (Philips 56 R) absorbing moisture in transit or during storage they are supplied only in airtight tins.

The manner of welding rail sections end-to-end can be divined from the simple arrangement in fig. 2. However, the shape of the rail cross-section calls for enclosure components that are more elaborate then those for flat plates. *Figs. 3a* and *b* show the components required and their positioning. Welding of rail sections begins at the foot of the rail. Here a difficulty arises that always gives trouble when massive objects are to be welded: the bulk of the rail remains cold, and hence initially the parent steel in the vicinity of the weld cools quickly, thereby becoming brittle. The difficulty may be overcome by delaying the cooling process. A simple way of doing so is to heat the foot with an oxyacetylene flame prior to welding, raising its temperature to about 400 °C. *Fig. 4a* shows the enclosure in position: foot and web of the rails have already been welded, and the welding of the head can now begin. The completed weld may be seen in fig. 4*b*.

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[2]) P. C. van der Willigen, De metallurgie van het lassen van staal, Lassymposium Utrecht 1957, page 25 (in Dutch).

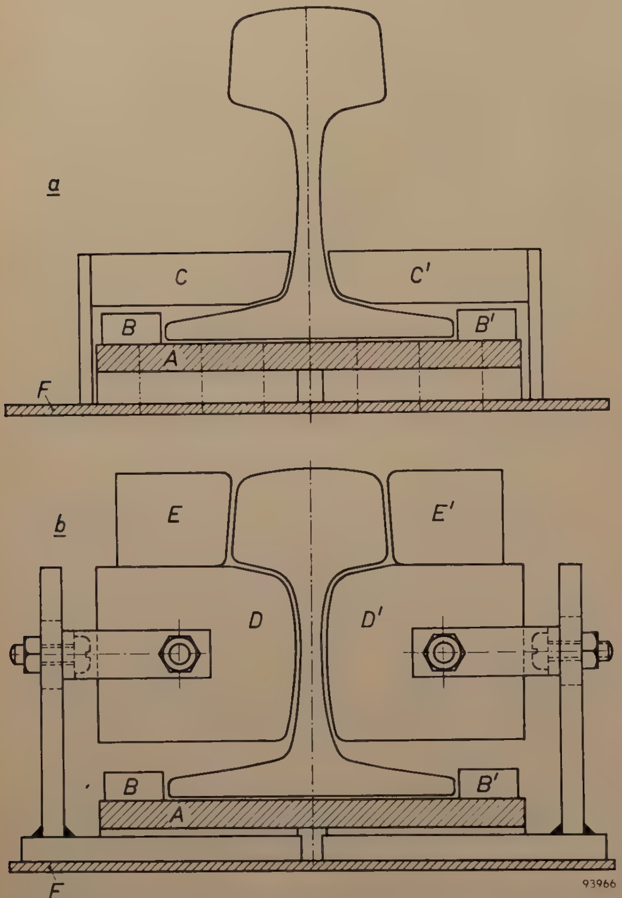

Fig. 3. Enclosure for welding rail sections. *a*) With the base-plate *A* and small blocks *B* and *B'* in position, the foot is welded. Blocks *C* and *C'* are then added and the lower part of the web is welded. *b*) Blocks *C* and *C'* are replaced by large blocks *D* and *D'*, and the welding of the web is completed. Adding blocks *E* and *E'* allows the head to be welded. Base-plate *A* and blocks *B . . . E'* are of copper. *F* is a steel plate on which rest the clamps for blocks *D* and *D'*.

Important advantages of enclosed welding are that no preparative machining and but little finishing are required and that, as already stated, it is a quick method. (Providing the gap in the rails is of the right size, the weld can be made and finished off within half an hour.) Further practical details are given in an article [3] that has appeared elsewhere.

Suitable enclosures can equally well be designed for other cross-sections; among the enclosures designed, there is one for rods of circular section such as used for the reinforcement of concrete.

A new welding method cannot be recommended unless both laboratory investigation and practical tests have proved its soundness. As regards the former, the Philips Laboratory at Eindhoven has made photographs of etched sections and radiographs of numerous specimens of enclosed welds. These testify to the absence of macroscopic inclusions (*fig. 5*). In addition, the Vickers-Lips hardness meter, which is ideally suited to the purpose [4], has been used to determine local variations in hardness in the weld itself, in the transition zones and at places beyond that part of the rail affected by the welding operation. Hardness curves obtained in this way are shown in *fig. 6*, from which it may be seen that the value of 300 VPN 10 [5] — which is still quite acceptable — is nowhere exceeded.

A great variety of methods are used by railway engineers in various countries for testing the mechanical endurance of rails. All such tests have been carried out by outside organisations, since Philips does not possess the appropriate equipment. *Pulsation tests* and *tup tests* are the most important kinds.

Pulsation tests, the purpose of which is to determine fatigue strength, have been conducted by the Netherlands Railways and British Railways, by T.N.O. [6] Delft (on behalf of Kloos and Sons' Workshops at Kinderdijk, Holland) and also at the Munich Technische Hochschule (on behalf of the Bamag Works at Butzbach, Germany). In these tests the operative quantity is P, the tensile stress in the outermost fibre of the foot of the rail. A stress P is caused to oscillate between a low minimum value P_{min} (e.g. one or two kg/mm^2) and a gradually increasing maximum value P_{max}. The fatigue strength is taken to be the value of P_{max} at which fracture just fails to occur after say 1 000 000 pulsations have been passed (however, the number of pulsations to which the test piece is subjected may be as high as 3×10^6, 5×10^6 or even 10×10^6). As always, finish-machining and polishing the weld has a good effect on the test results, since this removes surface irregularities at which fracture is

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[3] G. Zoethout, Het bekist lassen van spoorstaven, Lastechniek **23**, 274-277, November 1957 (in Dutch).

[4] H. T. Schaap, Hardheidsmeters en hun bruikbaarheid voor het onderzoeken van de overgangszones van lasnaden, Lastechniek **18**, 27-33, 1952 (in Dutch).

[5] VPN = Vickers' pyramid number. The figure 10 signifies that the measurement was made with a force of 10 kg.

[6] Dutch National Council for Industrial Research.

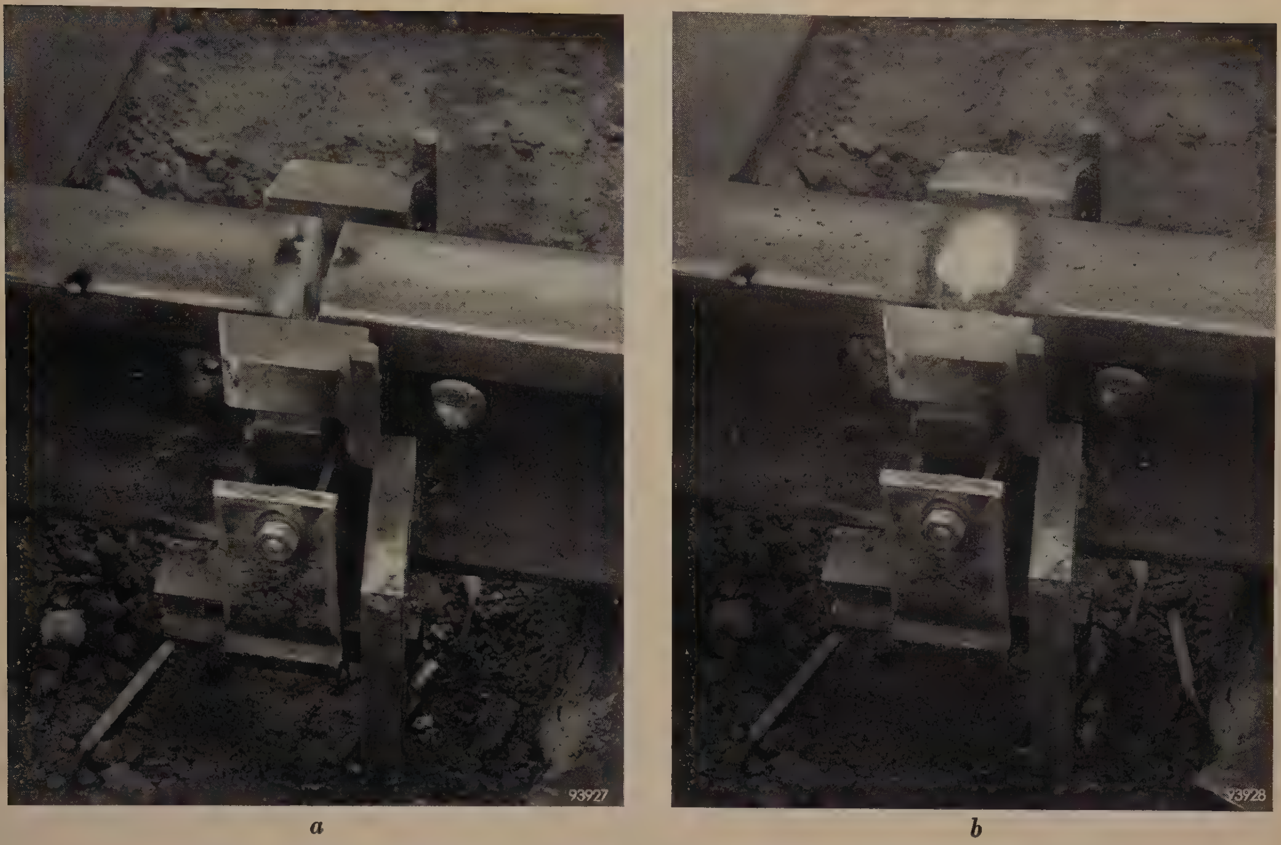

Fig. 4. Enclosed welding of rail sections. *a*) Foot and web have already been welded, and the welding of the head can now begin. *b*) The completed weld.

liable to nucleate. In tests by the Netherlands Railways, and in tests by British Railways, in which only the underside of the foot had been so finish-machined, the welds were found to have fatigue strengths approximately half that of the unwelded rail. Fatigue strengths but little inferior to that of the rail itself were found for the finished and polished specimens used for experiments at T.N.O. and Munich. For practical purposes it is recommended that at least the foot, the tread and the inside edge of the head should be finished and polished.

The Netherlands Railways have carried out so-called four-point bend tests, as illustrated in *fig.* 7. To prevent the rough surface of the weld prejudicing the reproducibility of the result, the load was applied a few centimetres on either side of the joint. Typical results appear in *Table I*; a mean fatigue strength of 19 kg/mm^2 was found for these specimens.

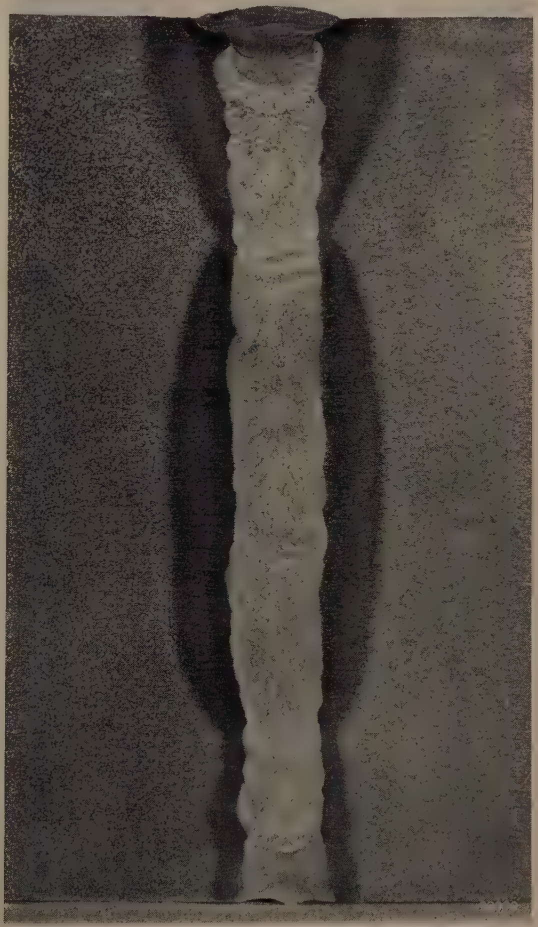

Fig. 5. Photograph of the etched cross-section of a weld made by the enclosed method between two rail sections (0.8 × actual size). No macroscopic slag inclusions are present. The dark regions on either side of the weld are the transition (heat-affected) zones.

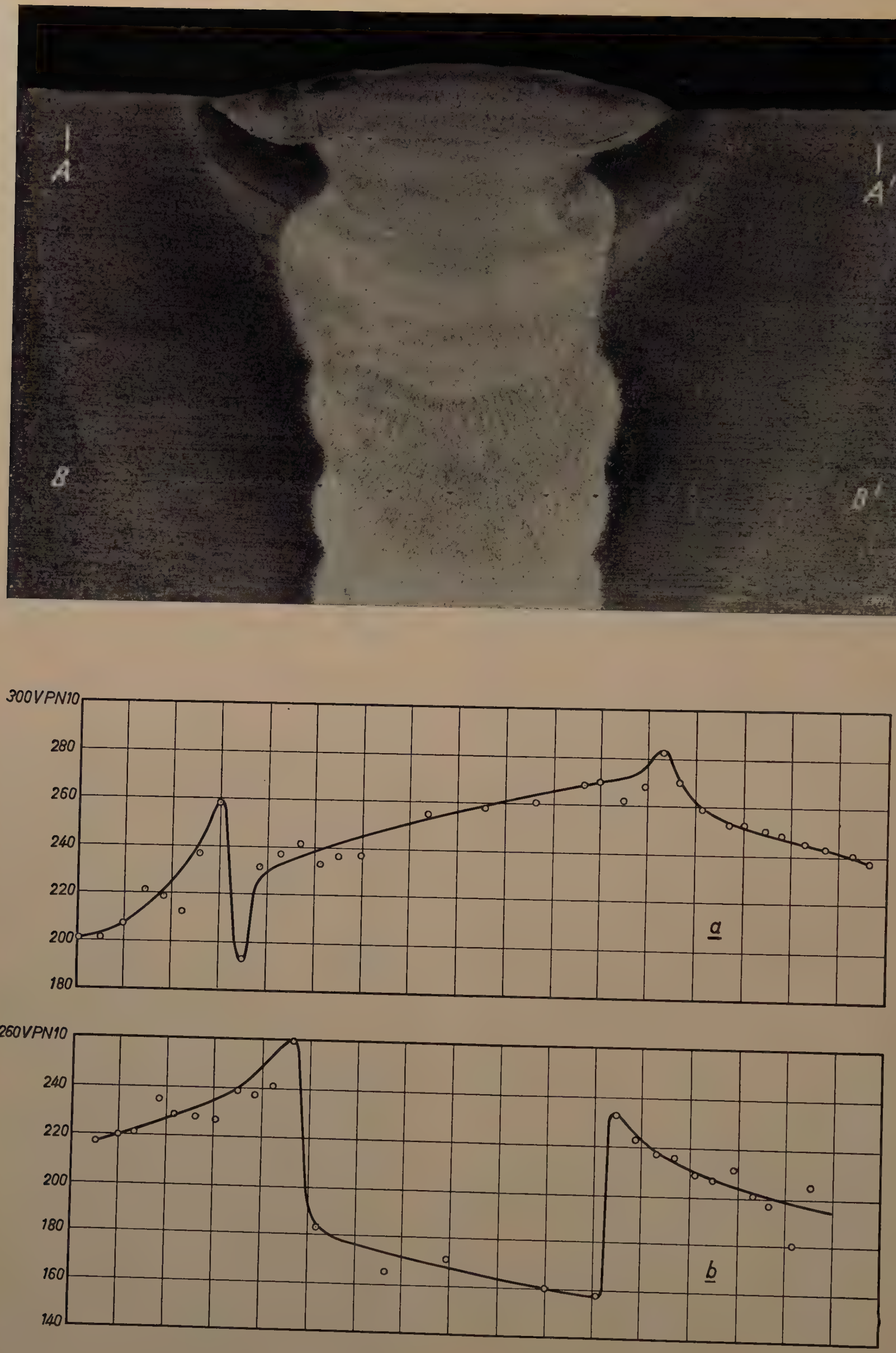

Fig. 6. The photograph shows a detail of the head of the weld appearing in fig. 5 (3.2× actual size). A row of indentations made by the Vickers-Lips hardness meter may be seen between *A* and *A'*. The hardness values determined from the indentations and expressed in Vickers units are plotted in curve *a*. Curve *b* corresponds to the indentations *B*-*B'*. All values occurring in the curves are well below 300 VPN 10 5).

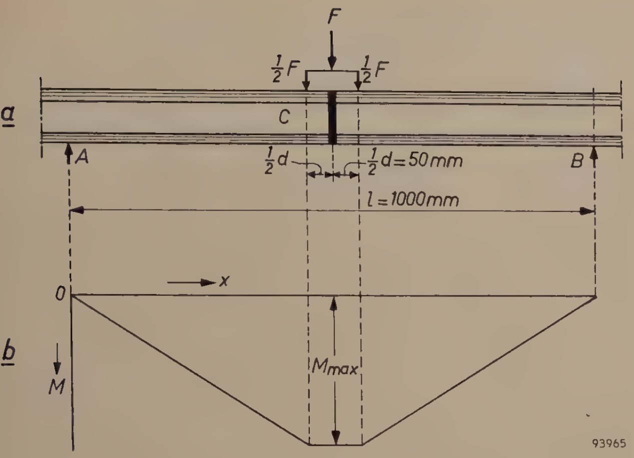

Fig. 7. Four-point bend test on enclosure-welded railway sections, as conducted by the Netherlands Railways. *a*) The specimen of welded rail *C* rests on supports *A* and *B* (distance apart $l = 1$ m) with the weld in the middle. A pulsating force $\frac{1}{2}F$ is applied at two points a distance of $\frac{1}{2}d = 50$ mm on either side of the weld; the weld has not been finished or polished, but at the points where the forces are applied the steel has its original smooth surface. *b*) Bending moment *M* as a function of length *x* along the specimen. Between the points of application of the load the bending moment has a uniform maximum value of $M_{\max} = \frac{1}{4}F(l-d)$.

Tests on behalf of British Railways, carried out in the Derby laboratory of the British Transport Commission, gave comparable results.

Table II contains the results of tests on two finished and polished weld samples. The tests were carried out at the Institute for Rail and Road Construction of Munich Technische Hochschule, under the direction of Prof. Meier. The results agree fairly well with those of corresponding tests done by T.N.O., in which small rods cut out of the foot of the weld sample constituted the test objects.

Table II. Pulsation tests carried out by Munich Technische Hochschule on two samples of finished and polished welds between rail sections weighing 49 kg/m. $P_{\min} = 1$ kg/mm².

Sample	$P_{\max}$, kg/mm²	Number of pulsations	Result
1	22	2 000 000	No fracture
	24	2 000 000	No fracture
	26	2 000 000	No fracture
	28	2 000 000	No fracture
	30	2 000 000	No fracture
	31.5	2 000 000	No fracture
	32.5	983 000	Fracture
		Total 12 983 000	
2	25	5 000 000	No fracture
	28	5 000 000	No fracture
	31	3 900 000	No fracture
		Total 13 900 000	

Tup tests have been conducted by the railway authorities in England (British Railways) and France (S.N.C.F.).

The British Railways tests, carried out in their laboratory at Redbridge, consisted in allowing a tup of 1¼ tons (1270 kg) to fall on the weld from a height that was progressively increased by 6 inches until fracture occurred. The distance between the two supports on which the test object rested was 1.20 m, and the rails weighed about 54 kg per metre. Eight out of ten welds fractured at 5.33 ton.metres, the remaining two at 7.00 ton.metres.

Table I. Results of pulsation tests carried out by the Netherlands Railways on six welds between rail sections, only the foot of the weld having been finish-machined. The rails weighed 46 kg per metre. $P_{\min} = 2$ kg/mm².

$P_{\max}$, kg/mm²	Number of pulsations	Result
17	2 700 000	No fracture
18	2 760 000	No fracture
19	3 160 000	No fracture
20	2 170 000	Fracture
20	2 430 000	Fracture
20	3 200 000	Fracture

In their laboratory at Moulin-Neuf, the S.N.C.F. carried out six tup tests whereby a tup of 1000 kg

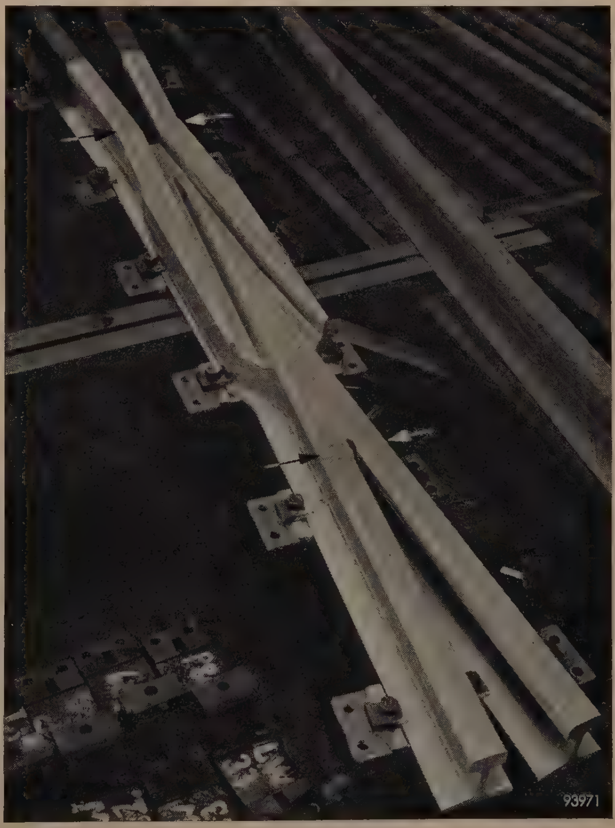

Fig. 8. Switchpoints, welded at both ends to normal rail sections. The joints are indicated by arrows. The section between the welds is milled out of a single steel block ("monoblock" construction).

was dropped on the weld from a height of 6 m and the work done in causing fracture was recorded automatically. Here the distance between the supports was 0.70 m and the rails were of the U33 type. The results obtained were 4.37, 3.21, 3.165, 4.83, 1.51 and 5.23 ton.metres. (They cannot be compared with the English results on account of the quite different conditions under which the tests were performed.)

We may conclude with some notes on the actual employment of enclosed welding on the railways. The workshops of Kloos en Zonen at Kinderdijk, to which reference has already been made, were the first to put the enclosed welding of rail sections into practice: some 90 switchpoints of the so-called "monoblock" type were welded to normal lengths of rail (*fig. 8*). These are now in use in the marshalling yard of the IJmuiden Blast Furnaces. Since then, welding by the new method has been done on a large scale in a number of other shunting yards in the Netherlands (Rotterdam and Eindhoven) and Belgium (Beringen). Having had good results with enclosed welding in a shunting yard near Toten, British Railways are now using the process on both branch and main lines. A number of gangs are proceeding with this work daily, and have already made thousands of welds.

G. ZOETHOUT.

AN EXPERIMENTAL INDUCTION-HEATING GENERATOR USING HYDROGEN THYRATRONS

by H. L. van der HORST and P. H. G. van VLODROP.

621.385.38:621.365.5

Hydrogen thyratrons, originally developed for the generation of modulating pulses for radar magnetrons, can also be used with advantage in induction-heating generators. As described below, the circuit is a modern version of the time-honoured spark-gap oscillator used in the early years of radio telegraphy.

The method of heating electrically conductive materials by inducing a current in them is widely used in industry. Its general advantage is that the heat can be applied very rapidly. In various heat treatments, for example surface hardening, a particular advantage is that the supply of heat can be accurately controlled and localized, and the fact that the method is very clean is of importance in melting processes. The object to be inductively heated is placed in the "work" coil, which is connected via a transformer to a generator, as represented schematically in *fig. 1.*

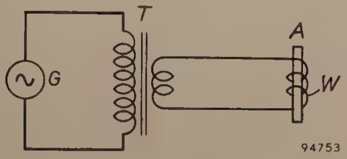

Fig. 1. Induction heating of a workpiece *A*. *W* work coil, *T* transformer, *G* generator.

With an eye to efficiency the choice of frequency is important. In an earlier article in this Review [1]) it was shown that a certain minimum frequency $f_{\min}$ is needed to ensure that the workpiece receives a large proportion of the power supplied to the work coil. The minimum frequency is higher the smaller the size, conductivity and permeability of the workpiece. Sizes, in particular, vary very widely; $f_{\min}$ lies in the region of the mains frequency only when the size of the workpiece corresponds to a quantity of the order of 1000 tons. In the majority of cases the quantities are smaller, and therefore a generator of higher frequency is needed to ensure a reasonable efficiency.

For workpieces ranging in weight from some hundreds to a few kilograms, *rotary converters* are suitable generators. They are designed for a fixed frequency not higher than about 10^4 c/s, and for power outputs up to about 1000 kW. Smaller objects are preferably heated at higher frequencies (10^4 to 10^7 c/s), generated by transmitting tubes. With the advance of transmitting-tube technique it is now possible to make electronic generators of 500 kW. They are used, among other things, for the preparation of alloys.

For the sake of completeness, and especially having regard to what follows, we must mention an older type of high-frequency generator, namely the spark-gap oscillator, in general use several decades ago in radio telegraphy. Here the charge built up in a capacitor discharges periodically via a spark gap through an oscillatory circuit, thereby producing in this circuit a damped oscillation.

In 1947 experiments were started in the Philips Laboratory at Eindhoven with the object of giving the spark-gap oscillator a new lease of life by substituting one or more senditrons for the spark gap. (Senditrons are rectifying tubes containing a mercury-pool cathode and a capacitative igniter electrode [2]).) Such an oscillator would have the advantage of a higher efficiency than an oscillator with a transmitting tube. It was found, however, that higher frequencies could be obtained with a certain type of thyratron (rectifying tubes with hot cathode, control grid and gas filling), namely the *hydrogen thyratron* developed for modulating magnetrons in radar transmitters. A thyratron of this type is shown in *fig. 2.* Hydrogen is used as the gas filling because it has the shortest de-ionization time. This property accounts for the fairly high frequencies (up to 10 kc/s) that can be generated with these thyratrons in the circuit described below. Owing to their higher arc voltage and the presence of a hot cathode, their efficiency is somewhat lower than that of senditrons, but still so much better than with transmitting tubes that no forced cooling with water or air is required. This is an important practical advantage.

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[1]) E. C. Witsenburg, Heating by high-frequency fields, I. Induction heating, Philips tech. Rev. **11**, 165-175, 1949/50.

[2]) T. Douma, A new method for converting D.C. energy into high-frequency A.C. energy with a high efficiency, specially intended for high-frequency induction heating, Communication News **10**, 52-68 and 69-82, 1949.

A generator with an oscillating vacuum tube and subject to variable load conditions, as is the case in induction heating, is liable to be overloaded unless safety measures are adopted, or at least a certain degree of skill exercised in operation. The generator described here excites damped oscillations, the damping varying with the load. The changes in damping are put to use for controlling the thyratrons in such a way as to render other precautions superfluous. This makes the generator very easy to operate.

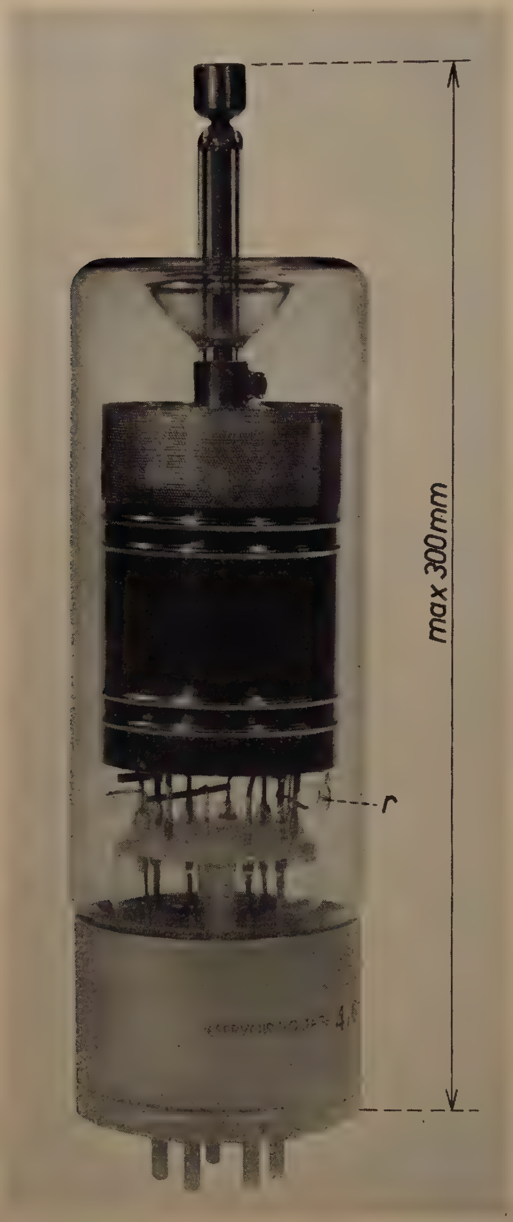

Fig. 2. Philips hydrogen thyratron type 5949. Max. peak anode voltage: 25 kV in both forward and inverse directions. Max. peak anode current: 500 A. Max. mean anode current: 0.5 A. The tube contains a hydrogen replenisher *r* in the form of a separate filament. As long as this is cold, practically all the hydrogen is adsorbed on its surface. The correct hydrogen pressure is established when this filament is connected across the prescribed voltage.

The circuit diagram is shown in its simplest form in *fig. 3*. The circuit works as follows. During the time that the thyratron *Th* is not conducting, the polyphase rectifier *R* (voltage V_0) charges the capacitor C_1, via a choke L_3, to a voltage that may be higher than V_0 (maximum $2V_0$); C_1 cannot, of course, loose any charge through the rectifier. Next, *Th* is ignited by a pulse on its control grid, so that C_1 can now discharge through the current-limiting choke L_1 and the thyratron into capacitor C_2. The transformer *T* provides the coupling with the work coil *W*, which contains the workpiece *A*. We can regard *T* as equivalent to a certain self-inductance L_2 and a resistance, and these, together with the capacitor C_2, constitute an oscillatory circuit. Since the self-inductance L_1 is a mere fraction of L_2, the capacitor C_1 discharges very rapidly into C_2. This excites the circuit L_2-C_2, which produces a damped oscillation. Meanwhile the thyratron has become non-conducting. The voltage on C_1 gradually rises again, and as soon as C_1 is once more sufficiently charged, the cycle can again be repeated by the next pulse on the grid of *Th*. Numerous variants of this circuit are possible. The advantage of the one described is that the thyratron cathode and one side of the rectifier and transformer can be connected to earth, which is no mean consideration in view of the high tension used ($V_0 = 10$ kV).

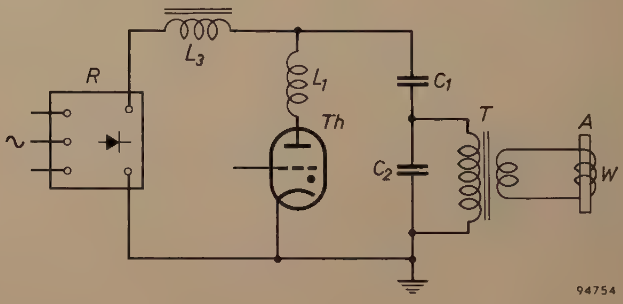

Fig. 3. Simplified diagram of an induction-heating generator with a hydrogen thyratron. Capacitor C_1 is charged up via choke L_3 by rectifier *R* (thyratron *Th* not yet conductive). When *Th* fires, C_1 discharges through the current-limiting choke L_1 and *Th* into capacitor C_2, which, with the self-inductance equivalent to the loaded transformer *T*, constitutes an oscillatory circuit. A damped oscillation then takes place in this circuit. *W* work coil, *A* workpiece.

In order for the circuit to function as described, it must comply with several conditions, which we shall now review very generally.

A closer analysis of the circuit [3]) reveals that it turns mainly on two parameters: the capacitance ratio C_1/C_2 and the self-inductance ratio L_1/L_2. The capacitance ratio influences the voltage v_{th} across the thyratron. In *fig. 4a, b* and *c* the variation of v_{th}/V_0 with time is shown for $C_1/C_2 = \frac{1}{2}$, 1 and 2, respectively, for the case of $L_2 \gg L_1$. It can be seen that v_{th} exceeds $2V_0$ neither in the forward nor in the inverse direction only when $C_1/C_2 = 1$; in that case, then, the thyratron is used to the best advantage as far as the voltage is concerned. In practice, however, the most favourable situation obtains at a somewhat smaller value of C_1/C_2, e.g. at $C_1/C_2 \approx 0.75$. The reason is that L_2, although larger than L_1, is in practice not many times larger (fig. 4 applies only to $L_2 \gg L_1$).

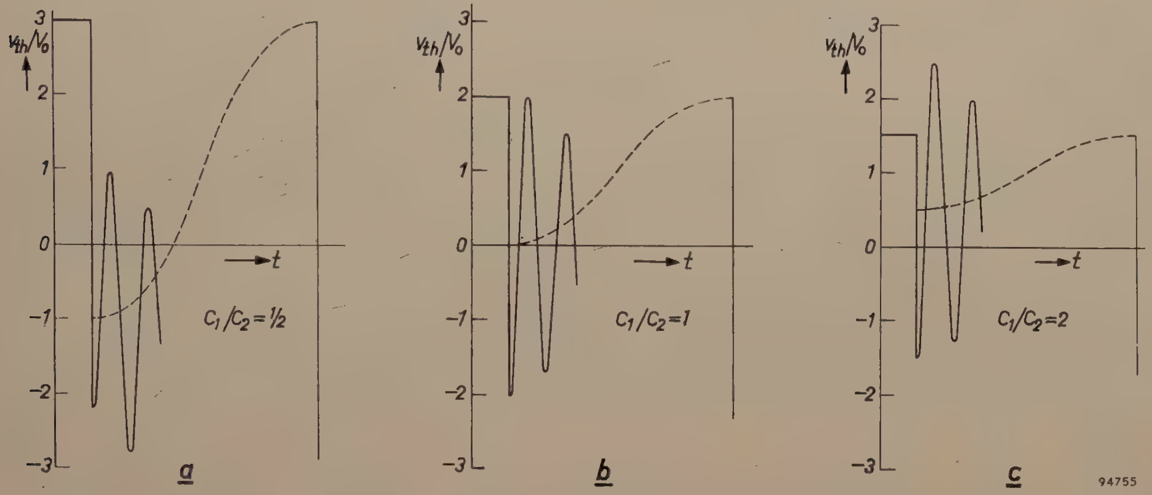

Fig. 4. v_{th}/V_0 as a function of time t for various values of C_1/C_2, in the case where $L_2 \gg L_1$. Only when $C_1/C_2 = 1$ does v_{th} remain less than $2V_0$ in *both* the forward and inverse directions.

For efficient operation it is essential that the thyratron should automatically become non-conducting in every cycle. The discharge current from C_1 flows through the series circuit made up of L_1, the thyratron and the parallel circuit L_2-C_2. In order to ensure automatic extinction of the thyratron the values given to the elements in this circuit must be such as to allow the current to drop to zero. Whether this can happen depends mainly on the self-inductance ratio L_1/L_2. In the article quoted under [2]) it was shown that when $C_1 \gg C_2$ (and neglecting the circuit resistance) the condition for the current to return to zero is: $L_1/L_2 \leq 0.217$. Where $C_1 \approx C_2$ (see above), L_1/L_2 must still remain below a certain maximum value, but in that case the maximum is higher, e.g. 0.35.

The self-inductance L_1 is one of the parameters determining the time needed for C_1 to discharge into C_2. To keep this time as short as possible, the value of L_1 should be as low as practicable. It should not, however, be lower than a certain minimum, as otherwise the current through the thyratron would exceed the maximum permissible peak rating. We can roughly estimate the minimum value of L_1 by neglecting the parallel circuit L_2, and disregarding the voltage drop in the thyratron (about 150 V) with respect to the voltage V_{C1} (e.g. 15 kV) to which the capacitor C_1 was charged. In this approximation the circuit consists only of the series capacitances C_1 and C_2 (equivalent to a single capacitance $C' = C_1C_2/(C_1 + C_2)$), and the self-inductance L_1. The current flowing through this circuit reaches a peak value

$$\hat{I}_{\text{a}} = \frac{V_{\text{C1}}}{\sqrt{\dfrac{L_1}{C'}}},$$

hence

$$L_1 = \left(\frac{V_{\text{C1}}}{\hat{I}_{\text{a}}}\right)^2 \frac{C_1C_2}{C_1 + C_2}.$$

With a type 5949 thyratron the maximum permissible value of $\hat{I}_{\text{a}}$ is 500 A. In practice, however, it is found that L_1 must be several times larger than appears from the last equation, as otherwise, immediately after extinction of the thyratron, the residual ionization would be so strong, and the negative potential on the anode would rise so rapidly, as to give rise to backfire.

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[3]) See Electronic Applications **18**, 57-67, 1957/58 (No. 2).

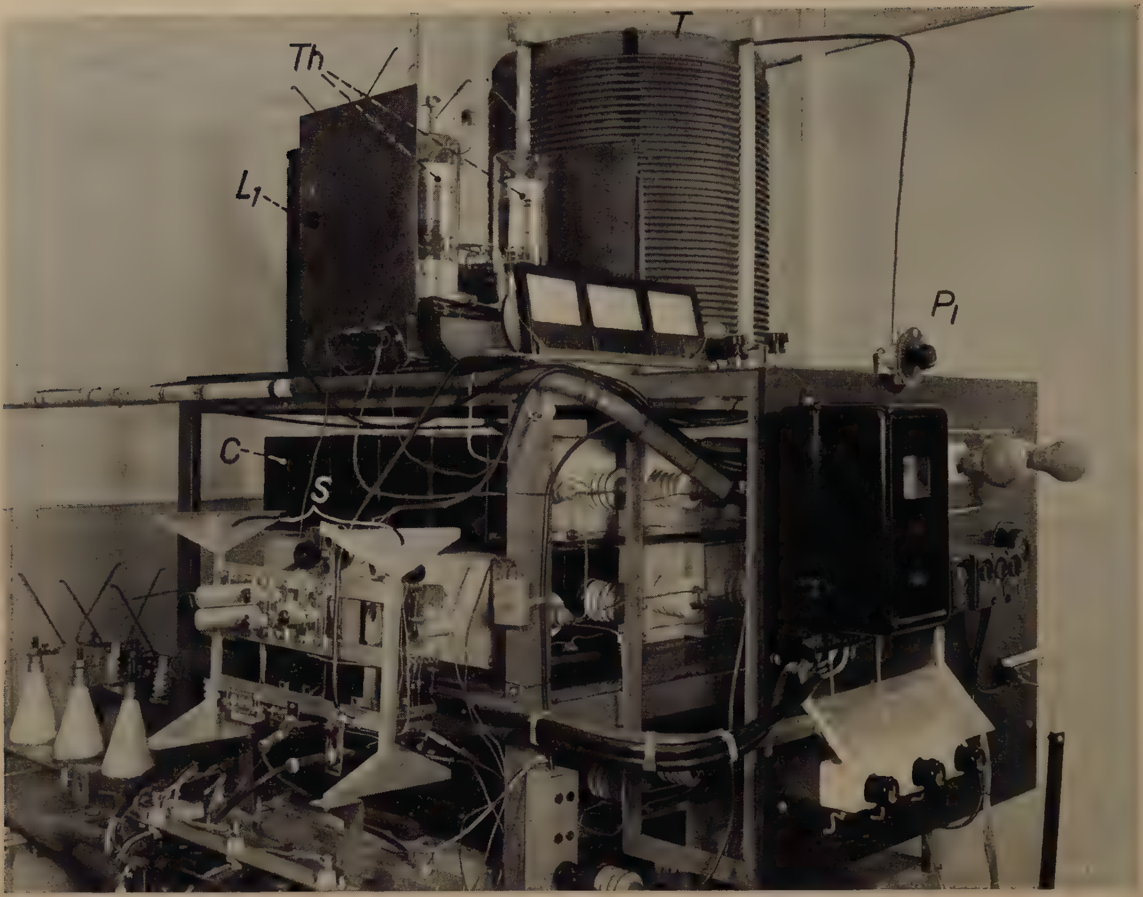

Fig. 5. Experimental set-up of an induction-heating generator containing two hydrogen thyratrons 5949 (*Th*) connected in parallel. L_1 is one of the chokes in series with the thyratrons. At *C* are the capacitors C_1 and C_2 (fig. 3). *T* transformer (see fig. 6). *S* control circuit (see fig. 7). P_1 power-control potentiometer.

The frequency f_0 at which the circuit L_2-C_2 oscillates is

$$f_0 = \frac{1}{2\pi\sqrt{L_2C_2}}\,.$$

The use of hydrogen as the gas filling in the thyratron permits working with frequencies f_0 as high as 10 000 c/s. This gives the following relation between L_2 and C_2:

$$L_2C_2 = \frac{1}{4\pi^2\times10^8}\ \text{henry} \times \text{farad}.$$

The foregoing considerations are a guide to the correct choice of C_1, C_2, L_1 and L_2.

There remains the self-inductance L_3 of the choke through which C_1 is charged (fig. 3). If the value of L_3 is too low, the thyratron, once it is ignited, will continue to carry current, resulting in a short-circuit across the rectifier. If L_3 is too large, it may happen in certain circumstances that C_1 will be charged to too high a voltage, so high that the thyratron can no longer be kept non-conducting. We have found by experiment that these two limiting values of L_3 are not very far apart.

In the present experimental set-up, shown in *fig. 5*, two thyratrons type 5949 are connected in parallel. In order to ensure that both tubes strike, a choke having a self-inductance $2L_1$ is connected in series with each tube; these two chokes replace the single choke L_1. The complete circuit is then made up of: $C_1 = 0.35$ μF, $C_2 = 0.48$ μF, $L_1 = 175$ μH (i.e. 350 μH in series with each tube), $L_2 = 525$ μH, $L_3 = 0.29$ H, $f_0 = 10$ kc/s and $V_0 = 10$ kV.

In an induction heater using an oscillating transmitting tube, the latter must always be kept matched to its load; this may be done by adjusting a capacitor and/or the coupling of the high-frequency transformer. This is not necessary with a generator working on hydrogen thyratrons, which simplifies operation. Moreover it permits the use of a low-loss transformer having a fixed and very tight coupling, the design of which is sketched in *fig. 6*.

For the experimental installation just outlined the *overall efficiency* has been determined, i.e. the ratio of the power P_2 developed in a given workpiece to the power P_1 which the rectifier draws from the mains (hence including the losses in the rectifier, in the transformer and in the work coil). For measuring P_2 a workpiece was used consisting of concentric steel cylinders, between which water was passed. P_2 was derived from the rate of flow of the water and its rise in temperature. The overall efficiency found was $P_2/P_1 = 5400\ \mathrm{W}/8490\ \mathrm{W} = 63.4\%$. It is probable that this figure could be raised to about 70% by improving the circuit design.

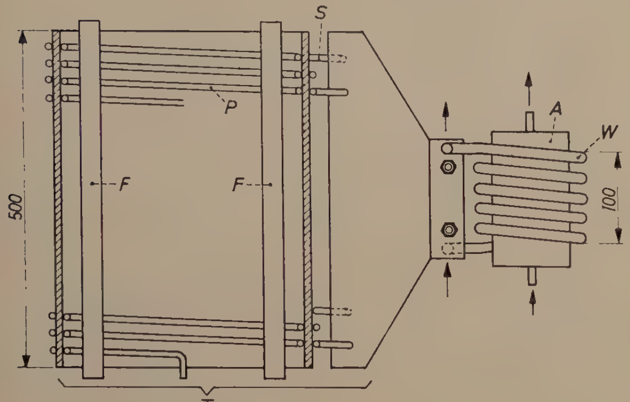

Fig. 6. Cross-section of transformer *T*. The primary *P* and the secondary *S* have an equal number of equally thick turns but those of *S* are interconnected so as to form a number of parallel-connected coils each of two turns. A very tight coupling is obtained by winding the primary concentrically inside the secondary and locating each primary turn exactly opposite to a secondary turn (see figure), and by the use of a "core" of 36 rods of ferroxcube *F*. The work coil *W* can, where necessary, be water-cooled. *A* is the workpiece, here also provided with water cooling for the purpose of determining the power developed. Dimensions in mm.

An important factor is the number of times C_1 discharges per second into C_2, i.e. the repetition frequency f_r of the pulses that ignite the thyratron. By regulating f_r it is a simple matter to vary the power between wide limits. The circuit for generating these pulses is shown in *fig. 7*. Section *A* contains a capacitor C_3 which is charged by a direct-voltage source via a resistor R_1. In parallel with C_3 is a (small) thyratron Th_1, which is initially kept non-conducting by negatively biasing the grid with a voltage from a potentiometer P_1. As C_3 charges up, the potential of point *Q* rises and the grid voltage becomes less negative until, at a given value, Th_1 strikes. Thereupon C_3 discharges through Th_1 during which process the cathode of Th_1 momentarily assumes a high potential, and this pulse ignites thyratron Th_2 in section *B* of the circuit. The energy accumulated in a lumped delay line L_5-C_5-L_6-C_6 now discharges via Th_2, giving rise to a rectangular pulse of constant duration (2 μsec) on the cathode resistance R_5 (the pulse duration is twice the transmission time along the delay line). These pulses are suitable for igniting the hydrogen thyratrons. Their steep trailing edge is conducive to rapid de-ionization. The repetition frequency f_r can be varied with P_1 (see also fig. 5) which controls the negative grid

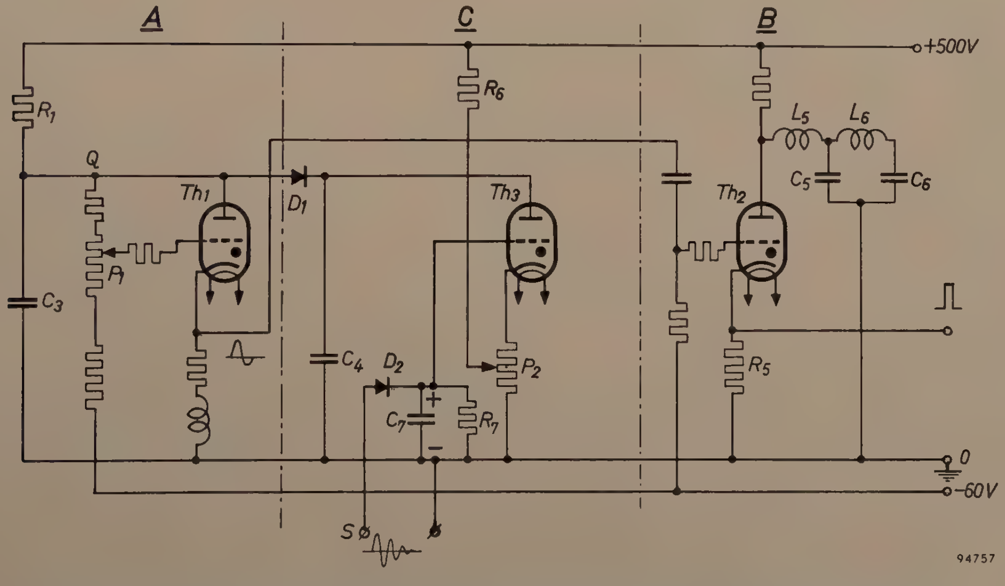

Fig. 7. Control circuit. In section *A* auxiliary pulses are generated which produce in section *B* the pulses for igniting the hydrogen thyratrons. Section *C* serves for automatically reducing the repetition frequency when the damping decreases (e.g. when the work is removed from the work coil). Th_1, Th_2 and Th_3 are low-power rare-gas thyratrons (type PL 5727, "Special Quality"). The repetition frequency is varied with potentiometer P_1. L_5-C_5-L_6-C_6 constitutes a delay line (pulse-forming network). For further explanation see text.

bias on Th_1. The higher f_r the larger is the mean anode current through the hydrogen thyratrons, the maximum permissible value of which is 0.5 A for each tube of type 5949. This sets an upper limit to f_r; in the present set-up it is about 250 c/s.

Not only is it possible in this way to control the power with a small potentiometer, but the power can also be automatically reduced when the workpiece is removed from the work coil. Section C in fig. 7 is used for this purpose. A capacitor C_4 and a thyratron Th_3 are connected, via a metal rectifier D_1, in parallel with capacitor C_3. The current flowing through resistor R_6 and through the lower part of potentiometer P_2 produces across P_2 a voltage which, as negative grid bias, normally keeps thyratron Th_3 non-conductive. Capacitor C_4 charges up via D_1 to the highest voltage reached by C_3, and retains this charge, the latter being prevented by D_1 from returning from C_4 to C_3. Thus, once it is charged up, C_4 performs no function until it has discharged through Th_3. When that happens it is effectively in parallel with C_3 and the time constant in section A increases from R_1C_3 to $R_1(C_3 + C_4)$; consequently the repetition frequency f_r drops correspondingly — e.g. to 1 pulse per second — and the power likewise. The ignition of Th_3 that initiates this process is triggered by the damping of the oscillatory circuit (T-C_2, fig. 3). For this purpose an auxiliary coil is fitted to the transformer T and connected between point S and earth as shown in fig. 7. From the damped alternating voltage induced in this coil a direct voltage is set up, via rectifier D_2, across R_7-C_7, this voltage constituting a positive component of the grid bias on tube Th_3. The voltages and the time constant R_7C_7 are such that, with normal (i.e. strong) damping, this direct voltage is insufficient to ignite Th_3, but quite sufficient when the damping is weak, for example when the work coil is unloaded. The repetition frequency thus drops suddenly to a low value as soon as the damping falls below a predetermined minimum, which is set by means of potentiometer P_2.

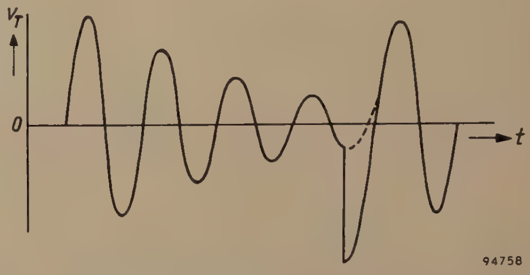

Fig. 8. Damped voltage waveform v_T across the oscillatory circuit. Re-ignition of the thyratron at a negative peak of v_T (i.e. negative with respect to earth) prevents unwanted voltage build-up across the oscillatory circuit.

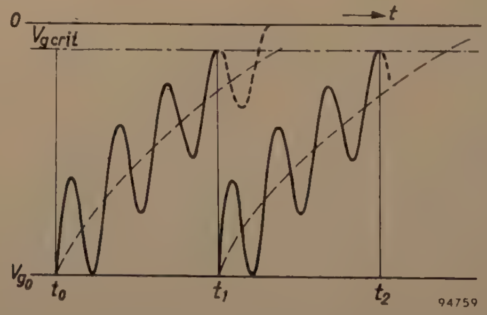

Fig. 9. Broken line: the exponentially rising grid voltage on Th_1 in fig. 7. V_{g0} negative bias. For synchronizing the ignition a damped alternating component is superimposed on the exponentially rising grid voltage. The critical grid voltage $V_{g\,crit}$ is then exceeded near a peak of the alternating voltage, so that the tube fires at $t = t_1, t_2$, etc.

Apart from the rapid discontinuous control of f_r as just described, automatic continuous control is also possible. The need for this arises when f_r becomes so high, or the damping so low, that when the hydrogen thyratron is again ignited, the previous oscillation still has an appreciable amplitude. The power then varies noticeably with the phase of the ignition with respect to the remaining oscillation. Unwanted voltage build-up across the oscillatory circuit is prevented by arranging for the tube to fire at an instant (*fig. 8*) that corresponds to a negative peak of the remaining oscillatory voltage across the thyratron. This synchronization is obtained by a small extension to section A in fig. 7, namely by adding to the exponentially rising grid bias of Th_1, a small damped alternating voltage which is again drawn from an auxiliary coil on the transformer. The resultant form of the grid voltage is then as shown in *fig. 9*. It can be seen from this that the ignition will take place near a peak of the ripple voltage. It is also clear, however, that the moment of ignition will depend somewhat on the damping: if, for example, the damping becomes weaker, the amplitude of the oscillating voltage component on the grid at the end of each period $1/f_r$ retains a larger value, and consequently the tube will fire somewhat earlier, f_r will be higher and the power greater. There are cases in which this effect is favourable (e.g. when an iron object reaches the Curie point, which, in view of the sharp decrease in permeability, makes an increase in the supplied power desirable) and there are also cases in which it is unfavourable. In the first category there is a need to intensify the said effect, and in the other category to compensate or even over-compensate it. Both can quite easily be done by including in the grid circuit of Th_1 (fig. 7) a direct voltage which, again, depends on the damped alternating voltage and which is obtained by rectifying the latter, exactly as described for thyratron Th_3. With the one polarity of this direct voltage the effect is intensified, and with the other it is attenuated or even reversed. In this way f_r can be made to vary continuously — and in the manner desired — with the damping.

With this incomplete discussion of the possibilities offered by control of the thyratrons, we have tried to show that the new generator can be designed in such a way as to dispense with the need for intricate safety measures and special operating skill. Against the limitation of the frequency to 10 kc/s there are also the advantages, already referred to, that the tubes require no forced cooling and that the efficiency is higher.

Summary. With a circuit similar in principle to the spark-gap oscillator used in the early days of radiotelegraphy, but in which the spark-gap is replaced by a hydrogen thyratron, damped oscillations can be generated with a frequency of up to 10 kc/s. Such frequencies are suitable for induction heating. The power can be controlled by varying the repetition frequency of the pulses that ignite the thyratron. A description is given of a control circuit for generating these pulses and for automatically varying the frequency and power. Since variations in the workpiece call for no change in capacitance or coupling, the generator is easier to operate than types employing transmitting tubes. Other advantages compared with the latter type of generator are that the thyratron requires no forced cooling and that the efficiency is higher.

A NOISE DIODE FOR ULTRA-HIGH FREQUENCIES

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The lower limit to the strength of the input signal that an amplifier can effectively amplify is determined by the noise added to the signal by the amplifier itself from its own valves and resistors. This contribution can be measured by connecting the amplifier to a noise source producing a noise signal of known strength (noise standard) [1]).

A commonly used noise standard is a saturated diode. The noise power produced by such a diode is proportional to the average number of electrons moving per second from cathode to anode, and hence proportional to the direct current flowing through the valve [2]).

If a diode of this type is to be used for noise measurements at very high frequencies, two main difficulties are encountered: 1) The finite transit time of the electrons begins to play a part, causing a reduction in noise current. 2) Between the actual noise source, which is situated between the electrodes of the diode and operates as a current source of infinite internal resistance, and the amplifier to be examined, is a network formed by the self-inductances and capacitances of the lead-in wires of the electrodes. The effect of this network becomes more and more strongly felt as the frequency rises. It is very difficult to make a quantitative estimate of the effect of these stray impedances.

The latter difficulty in particular soon becomes apparent at increasing frequency. If such a diode is to be used at very high frequencies, these stray impedances should be kept as low as possible. In the noise diode K81A, which was introduced a few years ago [3]), anode and cathode are fitted low down on the lead-in pins close to the glass base of the tube, making it possible to use this valve at frequecies up to 300 Mc/s.

We have now built a diode of extremely small dimensions that can operate at considerably higher frequencies. This noise diode (made only for experimental purposes), bearing the laboratory designation 10P, employs the same envelope and base as used for sub-miniature valves [4]); see *fig. 1.* The anode is a cylinder with a length of 4 mm and an internal diameter of 1 mm. The directly heated cathode is a 0.1 mm diameter tungsten wire strung in the axis of the anode. At an anode voltage of 100 V the diode operates well within the saturation region. The maximum permissible anode dissipation being 2 W (anode current 20 mA), the noise output is amply sufficient for measuring noise factors [2]). To keep the self-inductance of the lead-in wires as low as possible, the anode is mounted on four lead-in wires which are joined outside the tube, whilst one end of the filament is similarly connected to three lead-in wires (the other end, fixed to a tensioning spring, has only a single lead-in, being the filament-current return lead). To keep the electrode capacitances small, the getter holder is mounted quite separately in the envelope wall at the other end of the valve. The external parts of the lead-in wires are silver-plated, so that the desired connections can be readily soldered at a very short distance (approx. 2 mm) from the valve base.

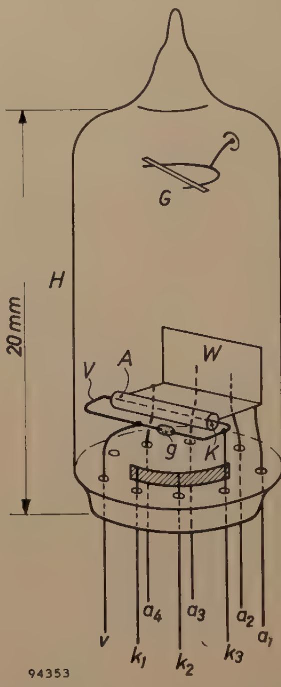

Fig. 1. Construction of a noise diode for very high frequencies (laboratory designation 10P). *H* envelope (sub-miniature valve); *A* anode; *K* filament with tensioning spring *V*; *W* cooling fin attached to the anode; *g* glass bead for insulation; a_1, a_2, a_3, a_4 anode lead-ins; k_1, k_2, k_3 cathode lead-ins; *v* return lead for filament current; *G* getter holder, sealed in the glass envelope.

If the cathode and anode connections were joined, a series resonant circuit consisting of the capacitance of the diode and the self-inductances of the lead-in wires would be formed having a resonance frequency f_0. In the evaluation of the noise factor of an amplifier connected to the diode, these stray impedances manifest themselves, at a frequency f, as a correction factor $\{1 - (f/f_0)^2\}^{-2}$. The uncertainty in determining f_0, however, renders this correction inaccurate as soon as f is no longer small with respect to f_0. For the new noise diode 10P, f_0 is found to be roughly 3500 Mc/s; at 1000 Mc/s, therefore, the correction factor does not amount to more than 18%. As a result of the very small dimensions, the reduction of the noise current due to the transit time of the electrons is as little as 3% at 1000 Mc/s. The sub-miniature noise diode 10P can therefore be effectively employed for noise measurements at frequencies up to 1000 Mc/s, i.e. well within the U.H.F. region.

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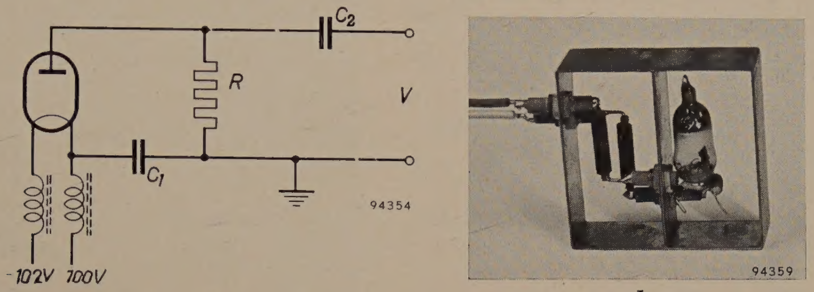
[1]) See e.g. F. L. H. M. Stumpers and N. van Hurck, An automatic noise-figure indicator, Philips tech. Rev. **18**, 141-144, 1956/57.

[2]) See e.g. G. Diemer and K. S. Knol, The noise of electronic valves at very high frequencies, I. The diode, Philips tech. Rev. **14**, 153-164, 1952/53.
A. van der Ziel, Noise, Prentice-Hall, New York 1954, page 63 ff.

[3]) This valve is nearly identical to the noise diode 10M mentioned in the article quoted in [2]), p. 155.

[4]) Cf. B. A. Cant, Problems in the construction of small radio valves, Philips tech. Rev. **18**, 217-222, 1956/57.

We shall now consider some of the various ways in which the diode can be connected in circuit as a noise generator.

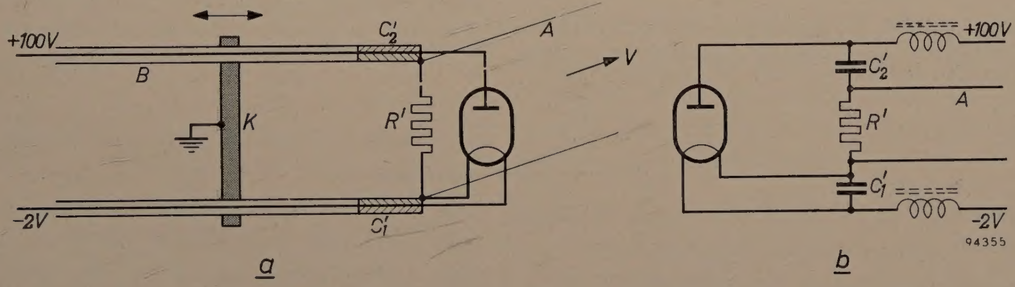


a *b*

Fig. 2. The noise diode 10P in a circuit with lumped elements. The input terminals of the amplifier under test are connected at *V*.

In the circuit of *figs. 2a* and *b* the noise current of the diode produces across the lumped resistance *R* a certain (calculable) noise voltage, which acts as the input voltage for the amplifier under test. The direct-current circuit and the high-frequency circuit are separated by the lumped capacitances C_1 and C_2. Since, however, C_1 and C_2 possess a fairly high stray self-induction (which reduces the above-mentioned resonance frequency), this circuit does not utilize the valuable properties of the valve 10P to full advantage.

More satisfactory are the arrangements shown in *figs. 3* and *4*, employing a Lecher system and a coaxial line respectively [5]). In the circuit of fig. 3*a* a noise voltage of known value is produced across the resistor *R'*. The amplifier to be examined is connected across *R'* via a Lecher line *A* of any desired



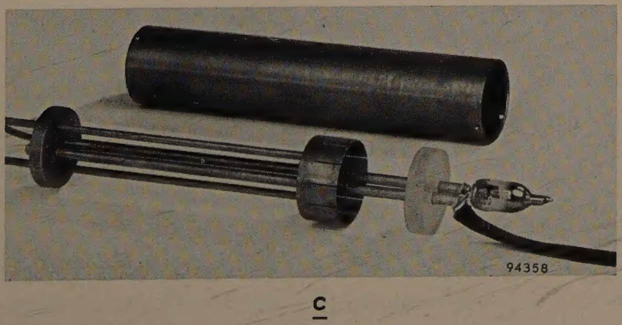


Fig. 3. *a*) Circuit diagram, *b*) equivalent circuit, *c*) photograph of a set-up with the noise diode 10P in a Lecher system. The amplifier under test is connected at *V* via a Lecher transmission line *A* of any desired length. By adjusting the shorting bridge *K* on the Lecher line *B* the valve capacitance is locally tuned away (i.e. compensated at the terminals of the resistor *R'*). In the equivalent circuit (*b*) the shorting bridge is omitted.

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[5]) The arrangement with the Lecher system has been designed and worked out by J. Stolk, that with the coaxial transmission line by N. van Hurck.

length. The separation from the direct-current circuit is here achieved by the capacitances C_1' and C_2' (see the equivalent circuit in fig. 3*b*), which consist in practice of ceramic tubes inside the hollow conductors of the Lecher line *B*. The influence of the overall valve capacitance (including C_1' and C_2') upon the noise voltage across *R'* is completely compensated by an appropriate adjustment of the shorting bridge *K* across this Lecher line: effectively, *R'* is shunted with a self-inductance whose reactance is exactly equal and opposite to that of the valve capacitance [6]. The stray self-inductances of C_1' and C_2' have no disturbing effect, since they merely contribute to the distributed self-inductance of the transmission line *B*: their presence merely has a slight influence on the position to which the shorting bridge has to be set to obtain the desired resonance.

Similar considerations apply to the arrangement with a coaxial transmission line, figs. 4*a* and *b*. At the right the transmission line is connected to the amplifier, whose input impedance is made equal to the characteristic impedance of the coaxial line (50 Ω); at the left the line is terminated with an impedance of the same value. Under these conditions the noise power supplied by the diode to the amplifier can be readily evaluated. It is true that the presence of the diode and the necessary aperture in the exterior conductor cause some disturbance of the field, so that the line is no longer perfectly matched, but the influence of this disturbance can be locally tuned away by means of a shorting piston as shown in the diagram.

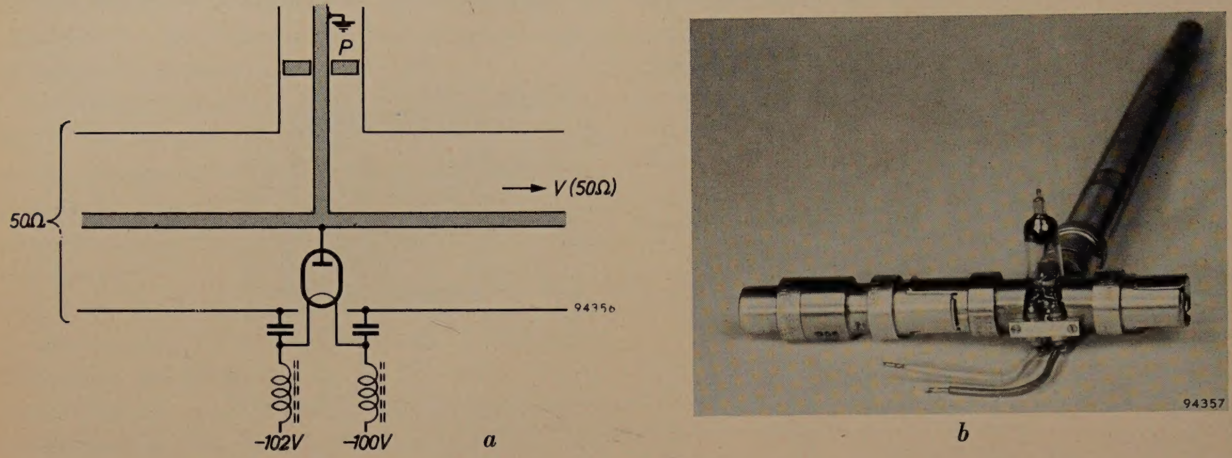

Fig. 4. The noise diode 10P in a coaxial transmission line arrangement. Here the disturbance of the field caused by the diode itself is locally tuned away by means of the shorting piston *P*.

H. GROENDIJK.

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[6] See e.g.: J. C. van den Hoogenband and J. Stolk, Reflection and impedance measurements by means of a long transmission line, Philips tech. Rev. **16**, 309-320, 1954/55.

ABSTRACTS OF RECENT SCIENTIFIC PUBLICATIONS BY THE STAFF OF N.V. PHILIPS' GLOEILAMPENFABRIEKEN

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2560: J. A. Hartveld: Moderne Fahrzeugbeleuchtung mit Fluoreszenzlampen (Elektrizitätsverwertung **32,** 213-224, 1957, No. 6-7). (Modern vehicle lighting with fluorescent lamps; in German, with comprehensive abstracts in English and French.)

General article on the various types of fluorescent lamps used in vehicles with accumulator or mains power supplies. For low-voltage (24 V) accumulators, rotary mercury jet inverters in conjunction with transformers offer the most efficient means of obtaining a suitable running voltage. An efficiency of 42 lumens/watt can be achieved for 40 W "TL" lamps. For 72 V accumulators, short 15 W "TL" C lamps can be fed directly, giving 30 lumens/watt. For 110 V supplies the 20 W "TL" C lamp has been developed. When power is available from the overhead lines or conductor rails, the supply may be D.C., 550 V, 600 V, 1500 V or 3000 V, or A.C., 15 000 V $16\frac{2}{3}$ c/s, or 25 000 V 50 c/s. For D.C. supplies the "TL" R lamp has been developed. For 25 000 V 50 c/s the "TL" S lamp is suitable after transformation of the supply. Owing to flicker, fluorescent lamps cannot be fed directly from $16\frac{2}{3}$ c/s supplies; in this case accumulators are used, or a separate D.C. generator. (See also Philips tech. Rev. **18,** 11-18, 1956/57.)

2561: F. K. Lotgering and E. W. Gorter: Solid solutions between ferromagnetic and antiferromagnetic compounds with NiAs structure (Phys. Chem. Solids **3,** 238-249, 1957, No. 3-4).

Several solid-solution series with NiAs structure have been prepared between a ferromagnetic $(x = 0)$ and an antiferromagnetic $(x = 1)$, viz. (*a*) CrTe$_{1-x}$Se$_x$, (*b*) Mn$_{1-x}$Cr$_x$Sb and (*c*) CrTe$_{1-x}$Sb$_x$. The system Cr$_{1-x}$Mn$_x$Te shows a miscibility gap. Saturation magnetizations have been measured between 20 °K and the Curie temperatures, and susceptibilities between the Curie temperatures and 850-1100 °K. In (*b*) and (*c*) the Curie and Néel temperatures decrease on addition of the other component, but do not simultaneously drop to zero. Notably in (*b*), compositions occur for which a Néel temperature is present above a Curie temperature. The saturation magnetization decreases with x in both systems, but in a different way. The magnetic properties found can be accounted for by assuming that the dominant exchange interaction is not a direct M-M interaction, but a superexchange interaction via the metalloid atom X, via the largest of the three angles M-X-M that occur for nearest neighbours M-X. These interactions are supposed to be strong and positive for Mn-Sb-Mn and Cr-Te-Cr configurations, strong and negative for Cr-Sb-Cr and weak for Mn-Sb-Cr configurations.

2562: G. Brouwer and S. van der Meer: A network analog of a statically loaded two-dimensional frame (Proc. Soc. Exper. Stress Anal. **15,** No. 1, 35-42, 1957).

With certain restrictions, a two-dimensional structure of rods may be represented by an electric circuit model consisting of resistor networks and feedback amplifiers. The mechanical quantities, such as loads, shearing forces, bending moments and deflections correspond to currents and potentials of the electrical model. The design of intricate frameworks can be carried out rapidly by means of an analog computor of the type discussed in this paper. A generalization to three-dimensional cases is possible.

2563: J. D. Fast: Einfluss der Gase beim Lichtbogenschweissen von Stahl (Schweissen und Schneiden **9,** 512-517, 1957, No. 12). (Effects of gases on the arc welding of steel; in German.)

The questions discussed in this paper include: interaction between gas and liquid weld-metal, the formation of blowholes, the detrimental effects of gases in the weld-metal, and aging phenomena and brittleness caused by gases.

2564: P. C. van der Willigen: Einfluss von Wasserstoff auf die Eigenschaften der Schweisse (Schweissen und Schneiden **9,** 517-521, 1957, No. 12). (Effects of hydrogen on the properties of welds; in German.)

This paper discusses the question of supersaturation with hydrogen, the formation of micro-cracks and macro-cracks, and the occurrence of fish-eyes.

2565: J. A. M. Dikhoff: Temperaturbestimmungen im Gleichstromkohlebogen (Proc. Colloquium Spectroscopicum Internationale VI, Amsterdam, 1956, published 1957 as an extra volume of Spectrochimica Acta and as a book by Pergamon Press, pp. 162-167). (Determination of temperature in D.C. carbon arcs; in German.)

Temperatures in carbon arcs have been determined by means of the intensity ratio between various spectral lines of zinc. A description is given of specially prepared electrodes permitting a steady supply of a small quantity of zinc during arcing. The result obtained for the centre of the arc, according to Addink's method, is a temperature of about 6100 °K. Apart from alkali metals, the evaporating materials affect this temperature only slightly. The results of temperature measurements in carbon arcs with argon or with argon + oxygen as discharge gas are also given and compared with the results published by Schöntag.

2566: N. W. H. Addink: Temperature measurements with reference to spectrochemical analyses (Proc. Colloquium Spectroscopicum Internationale VI, Amsterdam, 1956, published 1957 as an extra volume of Spectrochimica Acta and as a book by Pergamon Press, pp. 168-178).

It has been found that in the D.C. carbon arc there exists a relation between the ionization potential (V_i) of an element to be analysed and the ratio K/Q (K is the element concentration establishing a unit-intensity value of a spectral line of the element, which is excited in the constant-temperature D.C. carbon arc ($T = 6100$ °K), whilst Q means the same, except the excitation temperature is $\sim$6700 °K). It is shown that the elements can be divided roughly into two groups: those which are mainly excited in the column ($V_\mathrm{i} \geqslant 7.5$ V) and those which are excited in the mantle of the arc ($V_\mathrm{i} \leqslant 7$ V). A comparison with arcs described by other investigators is given. The knowledge of various temperatures has led to an improvement of the analysis carried out with these D.C. arcs. In an added supplement the lower limits of detection determined by various authors are compared.

2567: J. Ugelstad and J. de Jonge: A kinetical investigation of the reaction between amides and formaldehyde (Rec. Trav. chim. Pays-Bas **76**, 919-945, 1957, No. 11).

This paper deals with the kinetic measurement of the reaction between formaldehyde and the amides of carboxylic acids or urea. It is shown that the formation of a methylol amide proceeds by a bimolecular reaction, while its decomposition is a monomolecular reaction. The reactions are catalysed by H_3O^+ and OH^- ions and show general acid catalysis. General base catalysis was found in the urea-formaldehyde system, but could not be detected in reactions of formaldehyde with amides of carboxylic acids. A mechanism for the reactions of formaldehyde with amides in general (including urea) is proposed. In strongly alkaline solution the rates of decomposition of methylol amides were found to be independent of the hydroxyl-ion concentration. The acid dissociation constants of some methylol amides have values of about 10^{-14} moles.l^{-1} at 0 °C. The equilibrium constants of several amide-formaldehyde systems have roughly the same value (about 22 l.mole^{-1} at 25 °C), independent of pH (range $p\mathrm{H} = 2\text{-}12$). The rates of the reactions between formaldehyde and the various amides differ markedly. The relative rates found in alkaline solution are discussed.